

IOHN SMEATON.
CIVIL-ENGINEER F.R.S.

Died Oct.28.MDCCLXXXXII . Aged 68 Years -

Painted by M. Brown for Al. Aubert Esquire.

Engraved by M. Bromley and Published for the

Society of Civil Engineers, by W. Faden Feb. 14 1798.

## REPORTS

OF THE LATE

# JOHN SMEATON, F.R.S.

MADE ON

VARIOUS OCCASIONS,

IN THE COURSE OF HIS EMPLOYMENT

AS

A CIVIL ENGINEER.

IN THREE VOLUMES.

VOL. I.

LONDON:

PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER-ROW.

1812.

CHECKED

WESTERN SECTION.

# PREFACE

IT is with much satisfaction, the Committee of Civil-Engineers have, at length, so far accomplished their long wished for object, as now to present the public, with the first part of the works, of their late worthy and ingenious brother, Mr. John Smeaton; one of the greatest Engineers, that this, or perhaps any country, ever produced.

As, the members of this fociety have interested themselves so greatly, in the publication of the present work; and the author of it had so great a share in the first establishment, as well as, the subsequent management of the society, it may not be amiss in this place, to employ a few words, in giving a short account of it, before any thing is said more particularly of the publication itself.

The origin of the Society of Civil-Engineers, took its rife from the following circumstances. Before or about the year 1760, a new æra in all the arts and sciences, learned and polite, commenced in this country. Every thing which contributes to the comfort, the beauty, and the prosperity of a country, moved forward in improvement, so rapidly, and so obviously, as to mark that period with particular distinction.

The learned focieties extended their views, their labours, and their objects of refearch.—The professors of the polite arts associated together, for the first time; and they now enjoy a protection favourable to improvement, and not less honourable to real merit than to the public, and the Throne, which have, with one accord, promoted their prosperity.

Nor

Nor have these exertions failed of producing the adequate effects, comparing the present with the past state of things.

Military and naval establishments were made, or enlarged, to promote and extend the true knowledge on which these sciences depend.

The navy of England sails now uncontrouled in every part of the habitable world; and her ships of war defy the combined power of all other maritime nations.

It was about the same period, that manufactures were extended on a new plan, by the enterprize, the capital, and, above all, by the science of men of deep knowledge and persevering industry engaged in them.

It was perceived, that it would be better for establishments to be set down on new situations, best suited for raw materials, and the labour of patient and retired industry, than to be plagued with the miserable little politics of corporate towns, and the wages of their extravagant workmen.

This produced a new demand, not thought of, till then, in this country,—
internal navigation. To make communications from factory to factory, and
from warehouses to harbours, as well as to carry raw materials, to and from
such establishments, became absolutely necessary. Hence arose those wonderful works, not of pompous and useless magnificence, but of real utility,
which are, at this time, carrying on to a degree of extent and magnitude, to
which as yet there is no appearance of limitation.

The ancient barbours of this island, it may be said, have ever been neglected, considering the increase of its naval power, and a foreign commerce of which, there never has been an example, in the history of mankind. The seaports were, (I had almost said are,) such as nature formed, and providence has bestowed upon us; and they were but little better, previous to that period, notwithstanding some jettees and piers of defence, ill placed, had been

made,

made, and repeatedly altered, without knowledge and judgment, at municipal, not government expence.

This general fituation of things gave rife to a new profession, and order of men, called CIVIL-ENGINEERS.

In all the polished nations of Europe, this was, and is, a profession of it-felf, and by itself.—Academies, or some parts of such institutions, were appropriated to the study of it, and of all the preparatory science and accomplishments necessary to form an able artist, whose profession comprehends the variety of objects on which he is employed; and of which, the present work, is an example and a proof.

In this country, however, the formation of fueb artists has been left to chance; and persons leaned towards the public call of employment, in this way, as their natural turn of mind took a bias—There was no public establishment, except common schools, for the rudimental knowledge necessary to all arts, naval, military, mechanical, and others.

CIVIL-ENGINEERS are a felf-created set of men, whose profession owes its origin, not to power or influence; but, to the best of all protection, the encouragement of a great and powerful nation;—a nation become so, from the industry and steadiness of its manufactoring workmen, and their superior knowledge in practical chemistry, mechanics, natural philosophy, and other useful accomplishments.

When any one who has read the varied particulars of this publication, shuts, and lays it down for contemplation, he will reslect, on the natural talents and fagacity requisite in that mind, which applies to such a profession; on the patient application, necessary to acquire all the subservient learning, previous to the commencement of it; and, on the wonderful and varied powers, which this work exhibits.

The fame period gave rife also to an affociation of some gentlemen, employed as abovementioned. They often met accidentally, prior to that union, in the Houses of Parliament, and in Courts of Justice, each maintaining the propriety of his own designs, without knowing much of each other. It was, however, proposed by one gentleman, to Mr. SMEATON, that such a state of the profession, then crude and in its infancy, was improper: and that it would be well, if some fort of occasional meeting, in a friendly way, was to be held; where they might shake hands together, and be personally known to one another:—That thus, the sharp edges of their minds might be rubbed off, as it were, by a closer communication of ideas, no ways naturally hostile; might promote the true end of the public business upon which they should happen to meet in the course of their employment; without jostling one another, with rudeness, too common in the unworthy part of the advocates of the law, whose interest it might be, to push them on perhaps too far, in discussing points in contest.

Mr. SMEATON immediately perceived the utility of the idea, and at once embraced it. In March 1771, a fmall meeting was first established, on Friday evenings, after the labours of the day were over, at the Queen's-Head Tavern, Holborn. And, from a few members at first, it soon increased; so that in the space of 20 years, they amounted to 65 and upwards. But of these, there were only about 15, who were real Engineers, employed in public works, or private undertakings of great magnitude.

Among these, we find the names, of YEOMAN, SMEATON, GRUNDY, MYLNE, NICKALLS, JESSOP, GOLBORNE, WHITWORTH, EDWARDS, Jos. PRIESTLY, Major Watson, Boulton, Whitehurst, Rennie, Watt, and some others. The other members were either amateurs, or ingenious workmen and artificers, connected with, and employed in, works of engineering.

This affociation declared itself a society; and a register was kept, of the names and numbers of its members. Conversation, argument, and a social communication of ideas and knowledge, in the particular walks of each member,

member, were, at the same time, the amusement and the business of the meetings.

In this manner, sometimes well attended, and at other times not so, as the members were dispersed all over England, THE Society, proceeded until May 1792; when it ceased to exist, by mutual consent of the principal members.

Some untoward circumstances, in the behaviour of one gentleman, towards Mr. Smeaton, gave rise to the disunion. No one, was ever more obliged than that gentleman, (who is now deceased,) to Mr. Smeaton, for promoting him in business, and many essential offices in life. The offence given, was done away by an apology, at the desire of the company, and by the goodnature of Mr. Smeaton; but the remembrance of it had an effect on all present.

Afterwards, it was conceived and intended to renew this society, in a better and more respectable form. Steps were taken for that purpose, and Mr. SMEATON agreed to be a member.—But alas! before the first meeting could be held, he was no more. He died the 28th of October, 1792; and their first meeting was in April, 1793.

It was conceived, it would be a better plan, that the members should dine together, at a late hour, after attendance in Parliament; and pass the evening in that species of conversation, which provokes the communication of knowledge, more readily and rapidly, than it can be obtained from private study, or books alone.

The first meeting of this new institution,

THE SOCIETY OF CIVIL-ENGINEERS,

by Mr. Jessop, Mr. Mylne, Mr. Rennie, and Mr. Whitworth.

The constitution was agreed on, and afterwards acceded to by all;—That there should be three classes in the society: The first class, as ordinary Members, to consist of real Engineers, actually employed as such, in public or in private service. The second class, as honorary members, to consist of men of science and gentlemen of rank and fortune, who had applied their minds to subjects of Civil-Engineering, and who might, for talents and knowledge, have been real Engineers, if it had not been their good fortune, to have it in their power to employ others in this profession; and also of those, who are employed in other public service, where such and similar kinds of knowledge is necessary.—And, the third class, as honorary members, also to consist of various artists, whose professions and employments, are necessary and useful to, as well as connected with, Civil-Engineering.

The meetings are held at the Crown and Anchor, in the Strand, every other Friday, during the session of Parliament. And the list of members are of the

### FIRST CLASS,-ORDINARY MEMBERS.

WILLIAM JESSOP,
ROBERT WHITWORTH,
JOHN RENNIE, F. R. S. Ed.
ROBERT MYLNE, F. R. S.
JAMES WATT, F. R. S.—L. and Ed.
JAMES GOLBORNE,
Sir Thomas H. Page, Knt. F. R. S.
JOHN DUNCOMBE,
Captain JOSEPH HUDDART, F. R. S.
HENRY EASTBURNE,
WILLIAM CHAPMAN, M. R. I. A.
JAMES COCKSHUTT.

SECOND CLASS .- Honorary Members.

The Right Hon. Sir Joseph Banks, Bart. P. R. S.
Knight of the Order of the Bath, &c.
Sir George A. Shuckburgh Evelyn, Bart. F. R. S.
Mathew Bolton, Efq; F. R. S.
General Bentham,
Joseph Priestly, Efq;
Doctor Charles Hutton, F. R. S.
Henry Oxendon, Efq;
The Right Hon. the Earl of Morton, F. R. S.
John Lloyd, Efq; F. R. S.
Right Hon. Charles Greville, Efq; F. R. S.

THIRD CLASS .- HONORARY MEMBERS.

WILLIAM FADEN, Geographer,

Jesse Ramsden, F. R. S. Instrument-Maker, &c.

John Troughton, Instrument-Maker, &c.

John Foulds, Mill-Wright, &c.

Samuel Phillips, Engine-Maker,

Samuel Brooke, Printer,

John Watte', Land-Surveyor, &c.

It may be mentioned, as a mark of the Society's regard, that a tribute is always paid, after dinner, to the memory of their late worthy brother, John SMEATON. The publication of this work shews that their respect goes farther; by contributing a more substantial monument to his same and character.

The Society having learnt that Sir Joseph Banks had, for a confiderable fum, purchased all the manuscripts, designs, drawings of every sort, and all the Vol. I.

the papers of Mr. SMEATON, from his executors and representatives; with a conditional obligation, that if all or any of these papers should be published, and profit should arise from the publication, such profit or advantage should be made over to the said representatives, for their own use. This was a most liberal engagement on the part of Sir Joseph Banks; and as his avocations, in all the walks of science and natural history, are so extensive, it was proposed to him, and most handsomely acquiesced in, that the Society should undertake to perform the task of publishing the Reports only, with the condition thereto annexed; and that the loss, if any, should be defrayed by themselves, as well as, that the profits, if any, should go to Mr. SMEATON's representatives.

In February, 1795, four gentlemen stepped forward for this purpose, who, together with Sir Joseph Banks as one, and at the head of it, under the denomination of a Special Committee, have agreed to perform this service, such as it is, to the public; and to do it at their own risk, though not to their advantage, as abovementioned.

### This Committee confifts of

Sir Joseph Banks, Bart. Knight of the Order of the Bath, Prefident of the Royal Society, &c. &c.

Captain Joseph Huddart,

William Jessop, Efq;

Robert Mylne, Efq; and
John Rennie, Efq;

The Reports, only, were the great object of this Society, and of their Special Committee. These, they thought, would be of the greatest use to the profession, to teach actual and practical knowledge; as well to conceive advice and opinions given, as to convey them, with perspicuity and energy, to others.

Of these Reports, the present volume contains about one half; the remainder being intended for a second volume, if the present shall be approved by public encouragement.

The

The manner in which the reports are here arranged, is in chronological order, or the time in which they occurred, for each subject; with this variation, that all the several reports on the same subject, when there were more than one, made at different times, are here brought together, and placed immediately following each other, as may be observed in several parts of this volume, particularly the concluding subject of it, namely, the machinery at the Carron iron-works, upon which there were several reports.

As to Mr. SMEATON's style and language, he had a particular, and in some degree a provincial way of expressing himself, and conveying his ideas, both in speaking and writing; a way which was very exact and impressive, though his diction was far from what may be called classical or elegant. A good workman or artist, of humble pretensions, in that respect, is however always eloquent on the subject of which he is truly master. His language and words, therefore, and even the orthography, have been closely adhered to, without taking the liberty to make any alterations, unless perhaps sometimes in the change of a latter or a word, where a manifest deviation from grammar occurred, such as the author would of himself have altered, had he been the editor.

To this volume is prefixed a short account of the life and writings of Mr. SMEATON, taken partly from Dr. Hutton's Dictionary, and partly from additional Information supplied by the gentlemen of the committee.

A table of contents is also prefixed, and a general index is intended to be given at the end of the work.

OF

## THE LIFE, &c.

NR. JOHN SMEATON, F.R.S. a very celebrated Civil Engineer, and author of the enfuing Reports, was born the 28th of May, 1724, at Austhorpe, near Leeds, Yorkshire, in a house built by his grandfather, where the family have resided ever since, and where our author died the 28th of October, 1792, in the 68th year of his age.

Mr. SMEATON feems to have been born an Engineer. The originality of his genius and the strength of his understanding appeared at a very early age. His playthings were not those of children, but the tools men work with; and he had always more amusement in observing artificers work, and asking them questions, than in any thing else. Having watched some mill-wrights at work, he was one day, soon after, seen (to the distress of his family) on the top of his father's barn, fixing up something like a windmill. Another time, attending some men who were fixing a pump at a neighbouring village, and observing them cut off a piece of bored pipe, he contrived to procure it, of which he made a working pump, that actually raised water. These anecdotes refer to circumstances that happened when he was hardly out of petticoats, and probably before he had reached the 6th year of his age. About his 14th or 15th year, he made for himself an engine to turn rose-work, and he made several presents to his friends of boxes, in wood and ivory, turned by him in that way.

His friend and partner in the Deptford Water-works, Mr. John Holmes, wisited Mr. Smeaton, and spent a month with him at his father's house, in the year 1742, when consequently our author was about 18 years of age.

Mr. Holmes

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Mr. Holmes could not but view young Smeaton's works with aftonishment: he forged his own iron and steel, and melted his own metals: he had tools of every fort for working in wood, ivory and metals. He had made a lathe, by which he had cut a perpetual screw in brass, a thing very little known at that day.

Thus had Mr. SMEATON, by the strength of his gemus, and indefatigable industry, acquired, at 18 years of age, an extensive set of tools, and the art of working in most of the mechanical trades, without the assistance of any master, and which he continued to do a part of every day when at the place where his tools were; and few men could work better.

Mr. SMEATON's father was an attorney, and was defirous of bringing his son up to the same profession. He was therefore sent up to London in 1742, where for some time he attended the courts in Westminster-Hall; but finding that the profession of the law did not suit the bent of his genius, (as his usual expression was,) he wrote a strong memorial to his father on the subject, whose good sense from that moment left Mr. SMEATON to pursue the bent of his genius in his own way.

Mr. SMEATON after this continued to reside in London, and about the year 1750 he commenced philosophical instrument maker, which he continued for some time, and became acquainted with most of the ingenious men of that time.

This same year he made his first communication to the Royal Society; being an account of Dr. KNIGHT's improvements, of the Mariner's Compass. Continuing his very useful labours, and making experiments, he communicated to that learned body, the two following years, a number of other ingenious improvements, as will be enumerated in the lift of his writings, at the end of this account of him.

In 1751 he began a course of experiments, to try a machine of his invention for measuring a ship's way at sea; and also made two voyages, in company with Dr. KNIGHT, to try it, as well as a compass of his own invention.

### The COMMITTEE of CIVIL-ENGINEERS.

Felifoot, near Kendal, 30th October, 1797.

GENTLEMEN,

HE advertisement relative to the publication of Mr. SMEATON'S works, recalls to my mind a request made from you, through Mr. BROOKE, " that his daughters would affift in furnishing any anecdotes illustrative of " his life and character." And this recollection calls upon me to apolegize for the apparent neglect, as well as to account why an office so pleasant could be delayed for a moment. The fact is, Gentlemen, that, however immediate the impulse was to set about it, I soon found, in so doing, the task at once difficult and delicate.

The public ear, I am afraid, is satiated and fastidious; and the plain anecdotes of a plain man, like him, though interesting to individuals, could awaken little public curiofity, or perhaps, give still less satisfaction when awakened. And, extraordinary as it may feem, his family, probably less than others, are in possession of anecdotes concerning him; for, though communicative on all subjects, and stored with ample, and liberal observations on others; of Himfelf, he never spoke. In nothing does he seem to have stood more single, than in being devoid of that egotism, which, more or less, affects the world. It required some address, even in his family, to draw him into conversation directly relative to himself, his pursuits, or his success. Self-opinion, self-interest, and self-indulgence, seemed, alike, tempered in him, by a modesty inseparable from merit,-a moderation in pecuniary ambition, -a habit of intense application, and a temperance strict beyond the common standard. And, it is owing, perhaps, to this regulation, that, through a course of incessant satigue, and incredible exertion, from fix years old to fixty, the multiplicity of business, and presfure of cares, never had power to deaden his affections, or injure his temper.

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I fay,

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I fay, " fix years old to fixty," because while in petticoats, he was continually dividing circles and squares; all his play-things were models of machines, which destroyed the fish in the ponds, by raising water out of one into another. At school; -his exercises, in the law, to him not an agreeable destination; his dry, though useful attainments, occupied him through the day; -but mechanics, and his favourite studies, engressed the chief of every night. So that his mind appears to have indured an incesfant exertion through that period.

It was his maxim, " that the abilities of the individual, were a debt due to the common stock of public happiness, or accommodation!" This appears to have governed his actions through life; for the claim of fociety (thus become facred) his time was devoted to the cultivation of talents, by which he might benefit mankind; and thenceafter, to the unwearied application of them.

Indefatigable in the pursuits they led to, the public are in possession of all which Nature intrusted to him, or the measure of life allowed.

His friends know well how to appreciate the honest man, who valued them! And what he was in his family, every member of it could speak, if called upon, with equal gratitude, pride, and pleasure!

The arrangement of his time was governed by a method, as invariable as inviolable: for professional studies were never broken in upon, by any one; and these, (with the exception of stated astronomical observations,) wholly ingrossed the forenoon. His meals were temperate, and for many years restricted, on account of health, to rigid abstinence, from which he derived great benefit.

His afternoons were regularly occupied by practical experiments, or some other branch of mechanics. And not more entirely was his mind devoted to his profession in one division of his time, than abstracted from it in another. Himself devoted to his family with an affection so lively, a manner at once so cheerful and serene, that it is impossible to say, whether the charm of conversation, the simplicity of instructions, or the gentleness with which they were conveyed, most endeared his home. A home, in which from infancy we cannot recollect to have feen a trace of distatiffaction or a word of asperity to any one. Yet with all this he was absolute! And it is for casuistry in education, or rule, to explain his authority; it was an authority, as impossible to dispute as to define.

The command of his feelings, and submission of a temper, naturally warm, to reason and benevolence, were strongly illustrated by a circumstance, (in my recollection,) peculiarly trying to him. It arose from the conduct of a man formerly employed as a clerk, in whom having the highest confidence and esteem, he procured him a similar, though more lucrative, situation in a public office; where he ferved with a fidelity which in time promoted him to a station, of high trust and responsibility, (my father being bound, jointly with another gentleman, for his conduct, in a confiderable fum.) It were needless to say by what degrees in error this man fell; it suffices, that at last he forged a false statement, to meet the deficiency; that he was detected, and given up to justice. The same post brought news, of the melancholy transaction; of the man's compunctions and danger; of the claim of the bond forfeited; and of the refusal of the other person to pay the moiety ! - Being present when he read his letters, which arrived at a period of Mrs. SMEATON's declining health, so entirely did the command of himself second his anxious attention to her, that no emotion was visible on their perusal; nor, till all was put into the best train possible, did a word, or look, betray the exquisite distress it occasioned him. In the interim, all which could soothe the remorfe of a prisoner, every means which could save, (which did, at least from publie execution,) were exerted for him, with a characteristic benevolence, " active and unobtrufive."

The difinterested moderation of his pecuniary ambition, every transaction in private life evinced; his public ones bore the same stamp: and after his health had withdrawn him from the labours of his profession, many instances may be instanced by those, whose concerns induced them to press importunately for a resumption of it: and when some of them, seemed disposed to ensorce their entreaties by surther prospects of lucrative recompence, his reply was strongly characteristic of his simple manners and moderation. He introduced the old woman, who took care of his chambers in Gray's Inn, and shewing ber, afferted, "that her attendance sufficed for all his wants." The inference was indisputable, "for money could not tempt that man to forego his ease, leisure, or independence, whose requisites of accommodation were compressed within such limits!"

Before this, the Princess De Askoff made an apt comment upon this trait of his character; when, after vainly using every persuasion to induce him to accept a carte blanche from the Empress of Russia, (as a recompence for directing the vast projects in that kingdom,) she observed, "Sir, you are a great man, and I honour you! You may have an equal in abilities, persuasis, but in character you stand single. The English minister, Sir Roserr "Walpole, was mistaken, and my sovereign has the missortune to find one Man who has not his price!"

Early in life he attracted the notice of the late Duke and Duchess of Queensbury, from a strong resemblance to their favourite Gay, the poet. The commencement of this acquaintance was singular, but the continuance of their esteem and partiality lasted through life.—Their first meeting was at Ranclagh, where, walking with Mrs. Smeaton, he observed an elderly lady and gentleman fix an evident and marked attention on him. After some turns they at last stopped him, and the Duchess (of eccentric memory) said, "Sir, I dont know who you are or what you are, but so strongly do you resemble my poor dear Gay, we must be acquainted; you shall go home and sup with us; and if the minds of the two men accord, as do the countenance, you will find two cheerful old folks, who can love you

" well; and I think, (or you are an hypocrite,) you can as well deserve it."-The invitation was accepted, and, as long as the Duke and Duchess lived, the friendship was as cordial as uninterrupted; indeed, their society had so much of the play which genuine wit and goodness know how to combine, it proved to be, among the most agreeable relaxations of his life. - A sort of amicable and pleasant hostility was renewed, whenever they met, of talent and good humour; in the course of which, he effected the abolition of that inconsiderate indiscriminate play, amongst people of superior rank or fortune, which compels every one to join, and at their own stake too .- My father detested cards, and his attention never following the game, played like a boy. The game was Pope Joan, the general run of it was high, and the stake in "Pope" had accidentally accumulated to a sum more than serious. It was my father's turn by the deal, to double it, when, regardless of his cards, he bufily made minutes on a scrap of paper, and put it on the board. The Duchess eagerly asked him what it was? and he as coolly replied; "Your Grace will recollect the field in which my house stands may be about 5 acres, 3 roods and 7 perches, which, at thirty years purchase, " will be just my stake, and if your Grace will make a Duke of me, I pre-" fume the winner will not dislike my mortgage."-The joke and the lesson had alike their weight; they never after played but for the merest trifle.

The manly simplicity of deportment to his superiors, however, was alike free from pretention and servility; and an invariable consideration and kindness to his inferiors, produced a singular sentiment of veneration, in those who served him.

He always apprehended the stroke which terminated his life, as it was hereditary in his family; he dreaded it only as it gave the melancholy pos-fibility of out-living his faculties, or the power of doing good: to use his own words, "lingering over the dregs, after the spirit had evaporated!"

When this really did happen, the composure, with which he met it; his anxious endeavour to soften any alarm to his family; his resignation to the event; and his dignished thankfulness on finding at last, his intellect was spared, were

were every way worthy of himfelf.—Still his invariable with was " to be releafed!"

In the interim, (fix weeks) all faculties, and every affection, were as clear and animated, as at any period of his life. His memory was tenacious, and his ingenuity as active to relieve the inconveniencies of his then fituation, as such situation gave what be termed, trouble to those about him.

He expressed a particular desire and pleasure, in seeing the usual occupapations resumed; and reading, drawing, music and conversation excited the same interest, the same cheerful and judicious observations as ever.

He would fometimes complain of his own flowness, (as he called it,) of apprehension, and then would excuse it with a smile, saying, "It could not be otherwise, the shadow must lengthen, as the sun went down!" There was no sowness in fact to lament; for he was as ready at calculations, and as perspicuous in explanation, as at any former period. Some phenomena respecting the moon were asked him one evening, when it accidentally shone bright, sull into his room. When he had spoke fully on them, his eyes remained fixed upon it with a most animated attention, to us impressive; then turning them, on us with benignity, observed, "How often have I looked up to it with inquiry and wonder! To the period, when I shall have the vast and privileged views of an HEREAFTER, and all will be comprehension and pleasure!"

Shortly after, the end he had through life desired, was granted; the body gradually sunk, but the mind shone to the last; and in the way good men aspire to, he closed a life, active as useful, amiable as revered!

MARY DIXON.

In 1753 he was elected a member of the Royal Society; and in 1759 he was honoured with their gold medal, for his paper concerning the natural powers of water and wind to turn mills, and other machines depending on circular motion. This paper, he fays, was the result of experiments made on working models in the years 1752 and 1753, but not communicated to the Society till 1759; having, in the interval, found opportunities of putting the result of these experiments into real practice, in a variety of cases, and for various purposes, so as to assure the Society he had found them to answer.

In 1754, his great thirst after experimental knowledge led him to undertake a voyage to Holland and the Low Countries, where he made himself acquainted with most of the curious works of art so frequent in those places.

In December 1755, the Edystone Lighthouse was burnt down, and the proprietors, being defirous of rebuilding it in the most substantial manner, enquired of the Earl of Macclesfield, then President of the Royal Society, who he thought might be the fittest person to rebuild it; when, he immediately recommended our author. Mr. Smeaton accordingly undertook the work, which he completed with stone in the summer of 1759. Of this work he gives an ample description in a solio volume, with plates, published in 1791; a work which contains, in a great measure, the history of four years of his life, in which the originality of his genius is fully displayed, as well as his activity, industry and perseverance.

Though Mr. SMEATON completed the building of the Edystone Lighthouse in 1759, yet it seems he did not soon get into sull business as a Civil Engineer; for in 1764, while in Yorkshire, he offered himself a candidate for one of the receivers of the Derwentwater estate; in which he succeeded, though two other persons, strongly recommended and powerfully supported, were candidates for the employment. In this, he had the faithful and friendly support of Sir Francis Gosling, Alderman of London, and one of the Commissioners. That estate was forseited in the year 1715, and the revenues thereof were applied by Parliament, towards the fund of Greenwich Hospital. It consists of mines of lead, containing much silver, as well as lands.

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It required, better than common management, and above all, that knowledge absolutely necessary to bring mines of lead and coal to the most productive effect. This was the object of the Commissioners, and it has been amply repaid. Machines of all kinds, and better means on a great plan, were devised for a more easy and ample working these mines, by Mr. SMEATON: while, the correct judgment, patient industry, and great abilities and fincerity of Mr. Walton the younger, of Farnacres near Newcastle, (his partner in the duty of receiver,) taking upon himself the management and the accounts, left Mr. Smeaton, leifure and opportunity, to exert his abilities on these works, as well as to make many improvements in the whole of this estate of Greenwich Hospital.

By the year 1775 he had so much business, as a Civil Engineer, that he was defirous of refigning the appointment for that Hospital, and would have done it then, had not his friends prevailed upon him, to continue in the office about two years longer.

Mr. SMEATON having thus got into full business as a Civil Engineer, it would be an endless task to enumerate all the various concerns he was engaged in. A very few of them however may be just mentioned in this place. -He made the river Calder navigable & a work that required great skill and judgment, owing to the very impetuous floods in that river.-He planned, and attended for some time, the execution of the great, or Forth and Clyde, canal in Scotland, for conveying the trade of the country either to the Atlantic or German Ocean. When this work had been executed from the Forth towards the Clyde, as far as a point intended for the junction of a collateral canal to Glasgow, the work stopped, and was discontinued a considerable time, by the funds being exhausted. Before that period, Mr. SMEATON had declined accepting his falary, which was five hundred pounds a year, that he might not be prevented from attending to the multiplicity of other business; and conceiving the resident engineer, Mr. M'KELL, was fully competent to conduct it afterwards. After a lapse of some time, the work was resumed, by public aid, and has been carried on, and lately completed, under the direction of Mr. Whitworth, to the great benefit of trade and that country. On

On opening the great arch at London Bridge, by throwing two arches into one, and the removal of a large pier, the excavation, around and underneath the sterlings of that pier, was to considerable, as to put the adjoining piers, that arch, and eventually the whole bridge, in great danger of falling. The previous opinions of fine were positive, and the apprehensions of all the people on this head were fo great, that many persons would not pass over or under it. The Surveyors employed were not adequate to such an exigency. Mr. SMEATON was then in Forkflire, where he was sent for by express, and from whence he arrived in town with the greatest expedition. He applied himself immediately to examine the beldge, and to sound about the dangerous sterlings, as minutely as he could. The Committee of Common Council adopted his advice; which was, to re-purchase the stones of all the City Gates, then lately pulled down, and lying in Mongicide, and to throw them pell-mell, (or piere perdu,) into the water, to guard these sterlings, preserve the bottom from further corrolion, raise the sloor under the arch, and restore the head of water necessary for the water-works to it's original power; and this was a practice, he had before, and afterwards adopted on other occasions. Nothing shews the apprehensions of the bridge falling, more, than the alacrity with which his advice was pursued: the stones were re-purchased that day; horses, carts, and barges were got ready, and the work instantly begun, though it was Sunday morning. Thus Mr. SMEATON, in all human prohability, faved London Bridge from falling, and fecured it till more effectual methods could be taken.

In 1771 he became, jointly with his friend Mr. Holmes above-mentioned, proprietor of the works for supplying Deptjord and Greenwich with water; which, by their united endeavours, they brought to be of general use to those they were made for, and moderately beneficial to themselves.

Astronomy was one of Mr. SMEATON's most savorite studies; and he contrived and made several astronomical instruments for himself and friends. After fitting up an observatory at his house at Austhorpe, he devoted much of his time to it when he was there: even in preference to public bufiness, much of which he declined for the purpose of applying his attentions to private study, particularly to the subject of astronomy. About

About the year 1785 Mr. SMEATON's health began to decline; and, in consequence, he then took the resolution to avoid new undertakings in business as much as he could, that he might thereby also have the more leisure to publish some accounts of his inventions and works. Of this plan, however, he got no more executed than the account of the Edystone Light-bouse, and some preparations for his intended treatise on mills; for he could not resist the solicitations of his friends in various works. Mr. Aubert, whom he greatly loved and respected, being chosen chairman of Ramsgate Harbour, prevailed upon him to accept the office of Engineer to that harbour, an office established at that time, as, he had been occasionally confulted only, previous thereto; and to their joint efforts the public are chiefly indebted for the improvements that have been made there, within these few years; which fully appears in a Report that Mr. SMEATON gave in to the Board of Trustees in 1791, which has been published in various ways.

The powers of his mind were beginning to fail, in the observation of his intimate friends, and afterwards of all. He is known to have said, on talking of his health, that he found he had suffered more from the application he paid to the scheme, design, and proposition of a Canal from Birmingham to Worcester, (which was then very much contested in Parliament) than all the business he had ever met with.

Strong exertions were necessary; which, if he had been vigorous as he was wont, it would have sat easy upon him; but alas! with the deficiency then commenced, it was hard labour indeed, and thereby promoted, the ruin fast approaching, and much to be lamented.

This lamentable tale is told, for the instruction of those engaged, and so circumstanced, at that period of life, when the powers of the mind are borne down by the complication and vastness of an object submitted to it.

The bill for that work passed by a small majority; but the difficult and contested part of that work has not as yet been attempted. He was not the proposer, but the supporter of that proposition.

It had for many years been the practice of Mr. SMEATON to spend part of the year in town, and the remainder in the country, at his house at Austborpe. On one of these excursions in the country, while walking in his garden, on the 16th of September, 1792, he was struck with the palsy, which put an end to his useful life the 28th of October following, to the great regret of a numerous set of friends and acquaintance.

The great variety of mills constructed by Mr. SMEATON, so much to the satisfaction and advantage of the owners, will shew the great use he made of his experiments in 1752 and 1753. Indeed he scarcely trusted to theory in any case where he could have an opportunity to investigate it by experiment; and for this purpose he built a steam-engine at Austhorpe, that he might make experiments expressly to ascertain the power of the Old or Newcomen's steam-engine; which he improved and brought to a much greater degree of certainty, both in it's construction and powers, than it was before.

During many years of his life, Mr. SMEATON was a constant attendant on Parliament, his opinion being continually called for. And here his natural strength of judgment and perspicuity of expression had their full display. It was his constant practice, when applied to, to plan or support any measure, to make himself fully acquainted with it, and be convinced of it's merits, before he would be concerned in it. By this caution, joined to the clearness of his description, and the integrity of his heart, he seldom sailed, having the bill he supported, carried into an act of Parliament. No person was heard with more attention, nor had any one ever more considence placed in his testimony. In the Courts of Law he had several compliments paid to him from the Bench, by the late Lord MANSFIELD and others, on account of the new light he threw upon difficult subjects.

As a Civil Engineer, he was perhaps unrivalled, certainly not excelled, by any one, either of the present or former times. His building the Edystone any one, were there no other monument of his same, would establish his Lighthouse, were there no other monument of his same, would establish his character. The Edystone Rocks have obtained their name from the great character. The Edystone Rocks have obtained their name from the great wariety of contrary sets of the tide or current in their vicinity. They are statistically of contrary sets of the tide or current in their vicinity.

fituated nearly S. S. W. from the middle of Phymouth Sound. Their distance from the port of Plymouth is about fourteen miles. They are almost in the line which joins the Start and the Lizard Points; and as they lie nearly in the direction of vessels coasting up and down the Channel, they were unavoidably, before the establishment of a lighthouse there, very dangerous, and often fatal to ships. Their situation, with regard to the Bay of Bifeay and the Atlantic, is fuch, that they lie open to the swells of the bay and ocean, from all the south-western points of the compass; so that all the heavy seas, from the south-west quarter, come uncontrouled upon the Edystone Rocks, and break upon them with the utmost fury. Sometimes, when the fea is to all appearance smooth and even, and it's surface unruffled by the flightest breeze, the ground swell meeting the slope of the rocks, the sea beats upon them in a frightful manner, so as not only to obstruct any work being done on the rock, or even landing upon it, when, figuratively speaking, you might go to sea in a walnut shell. That circumstances, fraught with danger surrounding it, should lead mariners to wish for a lighthouse, is not wonderful; but the danger attending the erection leads us to wonder, that any one could be found hardy enough, to undertake it. Such a man was first found in the person of Mr. H. WINSTANLEY, who, in the year 1696, was furnished by the Trinity House with the necessary powers. In 1700 it was finished; but in the great storm of November, 1703, it was destroyed, and the projector perished in the ruins. In 1709 another, upon a different construction, was erected by a Mr. Rudverd, which, in 1755, was unfortunately confumed by fire.

The next building was under the direction of Mr. SMEATON, who, having confidered the errors of the former constructions, has judiciously guarded against them, and erected a building, the demolition of which feems little to be dreaded, unless the rock on which it is crected should perish with it. Of his works, in constructing bridges, harbours, mills, engines, &c. &c. it were endless to speak.

Of his inventions and improvements of philosophical instruments, as of the air-pump, the pyrometer, hygrometer, &c. &c. some idea may be formed from the lift of his writings inserted below.

In his person, Mr. SMEATON was of a middle stature, but broad and strong made, and possessed of an excellent constitution. He had great simplicity and plainness in his manners: he had a warmth of expression that might appear, to those who did not know him well, to border on harshnels; but, fuch as were more closely acquainted with him, knew it arose from the intense application of his mind, which was always in the pursuit of truth, or engaged in the investigation of difficult subjects. He would fometimes break out hastily, when any thing was said that was contrary to his ideas of the subject mand he would not give up any thing he argued for, till his mind was convinced, by the deducement of facts, before unknown to him, and by found reasoning. In all the social duties of life, Mr. SMEATON was exemplary; he was a most affectionate husband, a good father, a warm, zealous, and fincere friend, always ready to affift those he respected, and often before it was pointed out to him in what way he could serve them. He was a lover and an encourager of merit wherever he found it; and many persons now living are in a great measure indebted for their present situation to his affittance and advice. As a companion, he was always entertaining and instructive, and none could spend their time in his company without improvement.

As to the lift of his writings; besides the large work above-mentioned, being the History of the Edystone Lighthouse, and numbers of Reports and Memorials, many of which were printed, his communications to the Royal Society, and inferted in their Transactions, are as follow:

1. An Account of Dr. KNIGHT's Improvements of the Mariner's Compass. An. 1750, pa. 513.

2. Some Improvements in the Air-Pump. An. 1752, pa. 413.

3. An Engine for raifing Water by Fire; being an Improvement on SAVARY'S Construction, to render it capable of working itself; invented by M. DE MOURA, of Portugal. Ib. pa. 436.

4. Description of a new Tackle, or Combination of Pulleys. Ib. pa. 494.

5. Experiments on a Machine for measuring the Way of a Ship at Sea. An. 1754, pa. 532. 6. Description

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- 6. Description of a new Pyrometer. Ib. pa. 598.
- 7. Effects of Lightning on the Steeple and Church of Lesswithial in Corn-wall. An. 1757, pa. 198.
- 8. Remarks on the different Temperature of the Air at Edystone Lighthouse and at Plymouth. An. 1758, pa. 488.
- 9. Experimental Enquiry concerning the natural Powers of Water and Wind to turn Mills, and other Machines depending on a circular Motion. An. 1759, pa. 100.
- 10. On the Menstrual Parallax arising from the mutual Gravitation of the Earth and Moon, it's Influence on the Observation of the Sun and Planets, with a Method of observing it. An. 1768, pa. 156.
- of the Meridian. An. 1768, pa. 170.
  - 12. Observations on a Solar Eclipse. An. 1769, pa. 286.
  - 13. Description of a new Hygrometer. An. 1771, pa. 198.
- 14.. An Experimental Examination of the Quantity and Proportion of Mechanical Power necessary to be employed in giving different Degrees of Velocity to heavy Bodies from a State of Rest. An. 1776, pa. 450.

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OF THE

LIFF, CHARACTER, AND WORKS,

OF

MR. JOHN SMEATON, F.R.S.

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XXXII

# REPORTS, &c.

QUESTIONS proposed by the Magistrates and Town-Council of Dumfries to the consideration of Mr. SMEATON. October, 1760.

1st. WHAT is the easiest and most effectual method for preserving the town's grounds of Kingholme from the suture encroachments of the river?

2d. How can the navigation of the river Nith be most easily improved from Kingholme to Kelton, and the channel rendered less precarious than it is at present?

3d. It is defired that Mr. SMEATON may vifit the works carried on in the under part of the river, opposite to the Merse grounds of Netherwood, Cargin, and Laghall; and, upon considering the course of the river, and the situation and extent of these works, to give his opinion how far the navigation of the river will be bettered or injured by such works; and what amendments or alteration of them are necessary for preserving the navigation entire? And in case such works are attempted to be made by other heretors, what orders ought the Magistrates and Town-Council to give thereanent, as being guardians of the public navigation of this river; and how many seet or fathorn broad ought the channel to be kept free at those places?

In case it shall be thought proper or necessary that any of the works already erected ought to be destroyed, whether should the stakes be pulled up or knocked down, equal to or below the surface of the ground where they now are; and what ought to be done with such parts of the works as are of stone?

EBEN. HEPBURN.

JOHN DICKSON.

WM. CLARK.

REPORTS,

Vol. I. ANSWERS

ANSWERS to the questions proposed by the Magistrates and Town-Council of Dumsries, for the consideration of J. SMEATON.

HAVING carefully examined the course of the river Nith and the banks thereof, from Dumfries to Kirkonnel on the West side, and from Kelton to Dumfries on the East, both upon the flood and ebb of a spring tide, I am of opinion as follows:

Answer to question 1.—Where the banks, by the undermining of the water, tumble down, I would advise them to be sloped as low down as where the water begins to act, and to desend the foot of the slope by rows of stakes, single or double, according to the violence of the water's action, placed in a direction parallel to the bank, with binders to confine down a lay of sascines pointing towards the water. The slope of the bank must not be greater than to incline five feet backward for every yard of perpendicular height; the surface of this slope to be sodded, sown with hay seeds, or otherwise grassed over as far as the grass will grow, and the remainder covered with gravel, laid partly upon the sascines. The directions of the rows of stakes ought to be suited to the direction of the water, attempting as much as possible a right line or fair curve, avoiding as much as possible all sudden turns and irregularities.

Answer to question 2.- The channel of the river Nith has so many sudden turns and irregularities, that the tide spends itself among the sinuosities of the river, and in filling up wide spaces above, after having passed through narrower below, and is thereby prevented from mounting to so great a perpendicular height as it would otherwise attain, in the upper parts of the river near Dumfries in case the course was more straight, and had a more regular contraction; and this disadvantage is still the greater, as the space of time occupied by the tide of flood is so short, that it begins to ebb below, before the loops of the river, in the superior part, have time to fill to the level that the surface had been at in the lower, at high water. The navigation, therefore, seems incapable of any great improvements at any moderate expence, otherwise than by cutting a navigable canal, with proper locks and other works upon it, which can be done for much less than it would cost to make the river itself tolerably regular. But the way to prevent it from growing worse than it now is, must be by hindering it from becoming still more crooked, and growing still more wide above than below, giving as free a passage as possible to the tide of slood, especially in the most contracted places. Whatever contributes to this end tends to preserve it; whatever has contrary effect must be a detriment to it.

Answer to question 3.—In visiting those grounds and works, I observed as follows.

That Cargin Merse being situated on the concave side, or in the very bottom of a considerable

siderable loop of the river, the direction which the current receives from the superior grounds, on tide of ebb, and from the inferior, on tide of flood, both strongly tend to carry away the land of Cargin Merse, and thereby to render the loop still deeper: I am therefore of opinion, that the jettys and works there constructed, in as much as they contribute to prevent this loop from growing deeper, that is, the river from growing more crooked, they thereby contribute to the benefit of the navigation. But I am of opinion, that those jettys have been advanced too far into the river, whereby the course of the water has, in that part, been too much contracted; and also that, by being placed across the direction of the stream, they have contributed to hinder the free passage of the tide of flood, which would of consequence not fill the upper part of the river to so great perpendicular height, as has been already mentioned. However, as those jettys have in some measure answered one good purpose, viz. that of preventing the river from falling into a deeper loop in that place, and as it might be of dangerous consequence to disturb the body of sleech there gathered, by totally rooting up those jettys, I am of opinion, that fuch of the jettys as run across, or intercept the current, should be levelled with the present surface of the sleech, which may be done either by driving down or sawing off the stakes. As to the jettys that have been formed on the Netherwood side, as they don't feem to have contributed to fave the land, or to have answered any one purpose whatsoever, nor do they seem to produce any other effect than that of contracting the river in this, the otherwise narrowest part, and that of intercepting the current on tide of flood, both which, considering the large wide bay just above, and the various meandrings still higher, together with the smallness of the time that the tide of flood acts at this place, I am of opinion, that those jettys are very prejudicial to the navigation, and therefore think, that all of them, whether of wood or stone, should be pulled up, or otherwise levelled with the present bed of the river on which they stand. As to the jettys and works which have been raised upon the Merse grounds of Laghall, such as are contiguous to those of Cargin should be served in the same manner as has been mentioned concerning those of Cargin; but as to the rest, they are either so inconsiderable, or so placed, as to produce no sensible effect on the navigation. With respect to future works for preserving or gaining of land, provided they are so contrived as to shorten the course of the current, leaving the channel of the river of such a width, as to be wider than the medium width of half mile above, and narrower than the medium width for half a mile below; at the fame time carrying the weir fence, or advanced work, parallel to the natural direction of the current, reducing it, as near as may be, to a right line or fair curve, without sudden elbows and irregularities; laying also the banks or interior works smooth, and sloping, so as not to catch hold of and entangle the current of the tide of flood: I am of opinion, that all fuch works ought to be encouraged, as being advantageous to the navigation of the river.

Austhorpe, 28th Nov. 1760.

J. SMEATON.

QUESTIONS offered by Robert Maxwell of Cargin to the confideration of Mr. Smeaton.

HE Merse grounds of Cargin belonging to Mr. MAXWELL, are situated on the west side of the river Nith, opposite to the Merse belonging to Mr. Johnston, of Netherwood, on the east side of the river.

The Merse of Cargin for many years had been greatly injured by the river, until Mr. Maxwell raised weirs, or small creals, for desending his property from suture encroachment. Mr. Johnston, late of Netherwood, made works of the same nature on his side, which extend a considerable way higher up the river than Mr. Maxwell's, and opposite to works of the like construction creeted on the other side by Mr. Corrie, an heretor adjoining to Cargin, on the north or upper side.

While these works were carrying on, the Town Council (as guardians of the navigation of the river) interposed their authority, and, on a visitation thereof, appointed certain parts of the works, on both sides, to be removed, as being prejudicial to the public navigation. This order having been intimated to the whole heritors concerned, they agreed to comply therewith, and became bound in writing to remove the works pointed out as being so injurious. Accordingly Messas. Maxwell and Corrie did remove such parts of their works as were ordered, and fixed posts or pearches on what remained, for the direction of mariners. The other heretor, Mr. Johnston, did not remove a stick or stone of his; on the contrary, his heir and successor is now insisting to have the whole of Mr. Maxwell's works removed, as being hurtful to his, Mr. Johnston's, property, and to the public navigation.

It is therefore defired that Mr. Smeaton will view the works on both sides, and, upon considering the situation and extent of them, to give his answer to the following questions.

1st. How far were these works necessary for preserving the Merse of Cargin; and how can they be further secured, without injuring the navigation of the river, or the private property of others?—In considering this question it is to be observed, that by the situation of the opposite grounds of Netherwood, and the higher works thereon, which extend far into the channel, the force of the land flood and ebb tide, as well as the current of the flowing tide, is thrown with much violence on the bosom of Cargin Merse, which has nothing but

these works to repel the force of it; so that MR. SMEATON will please to consider what would have been the natural consequence had such work not been made.

Question 2.—How far are the works on Cargin side prejudicial to public navigation? And please also consider whether works of this kind, raised in defence of private property, are illegal and unprecedented; and whether they tend to hurt public navigation, and injure the private property of an opposite heretor.

QUESTIONS offered by Robert Maxwell, of Cargin, anent his work on the fide of the river Nith, to the confideration of Mr. J. SMEATON.

I T is defired that MR. SMEATON, in visiting the river, will view and consider the course of the river, the stoods and tide, and the situation of the grounds and works constructed thereon, upon the Merses of Cargin and Netherwood, and give his answers to the sollowing questions.

- 1st. Whether from the course of the river, and the situation of the opposite ground, the Merse of Cargin is exposed to the sorce of the land flood and ebb tide, and also to the current of the flowing tide; and if works were not therefore necessary, for desending Cargin Merse from the suture encroachments of the river?
- 2d. Whether the work already erected on Cargin Merse can hurt or prejudice the opposite Merse of Netherwood; and whether these works can be deemed illegal and unprecedented, as being injurious to the opposite grounds?
- 3d. How can these works be secured or improved, in the easiest and most effectual manner, for preserving Cargin Merse, without injuring public navigation, or the private property of neighbouring heretors?

ROBERT MAXWELL.

ANSWER

ANSWERS to the Questions offered by Robert Maxwell of Cargin, anent his Works on the side of the River Nith, by John Smeaton.

### Answer to Question 1st.

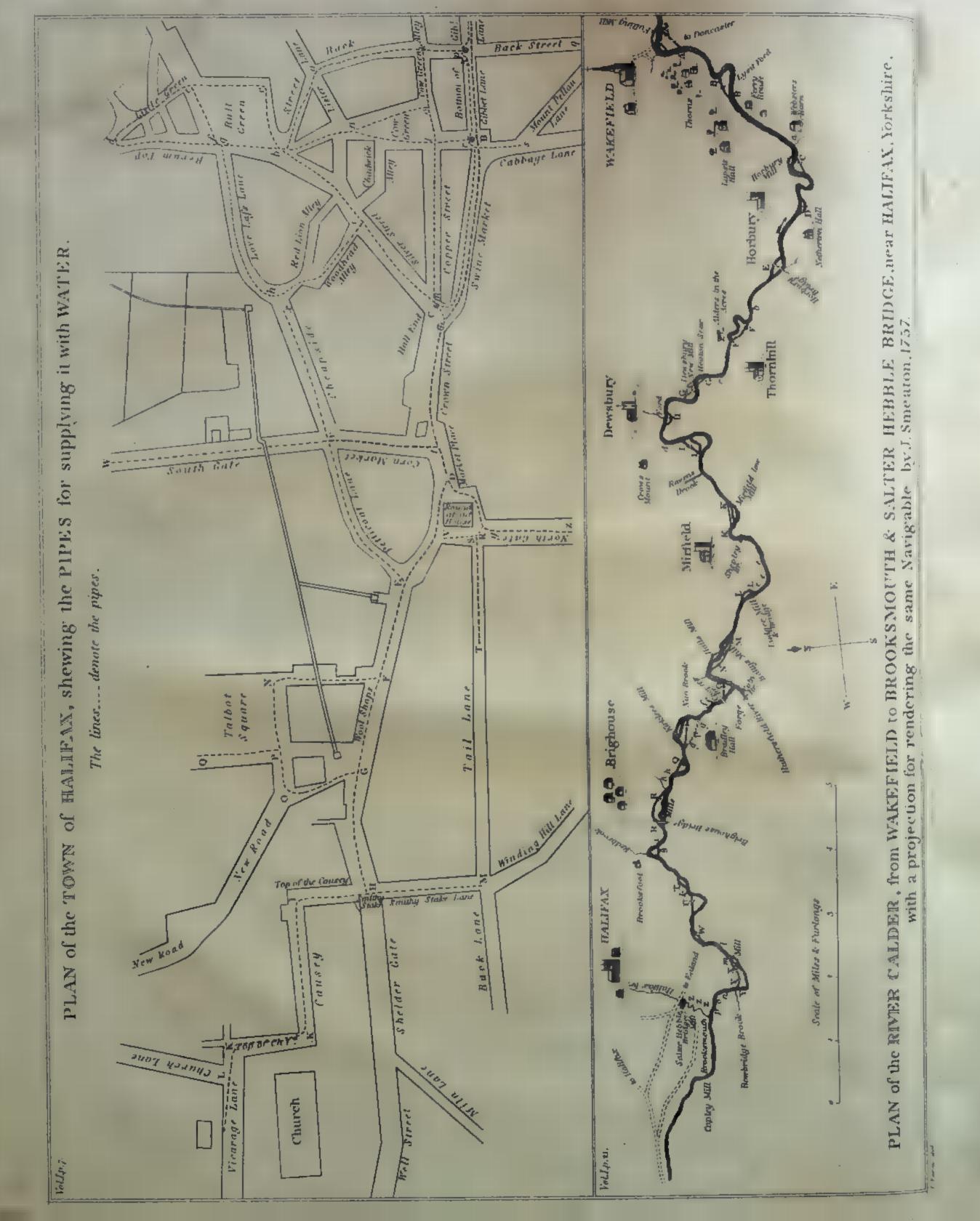
CARGIN Merse laying in the bottom, or most concave part, of a considerable loop of the River Nith, is by its situation exposed to the principal action of the slood and ebb tides, and also to that of the land floods; and the natural soil being of a very loose nature, artificial works were absolutely necessary, for the defence thereof from suture encroachments of the river, as without this, the natural effect of the currents would be, to make this loop of the river still deeper, by carrying away the soil of Cargin Merse.

Answer to the 2d question.—As Cargin Merse, notwithstanding what has been done, is still on the concave side of a deep loop of the river, the principal force of the current is still exerted on that side; and as the opposite grounds lay upon the convex side, they cannot be sensibly affected thereby; and those above, or below this concavity, are at too great a distance to be thereby affected. Works for this purpose are frequently made, and if not advanced further than what has been known to have been firm ground in the memory of man, I apprehend cannot be deemed illegal; but this part of the question more properly belongs to the laws.

Answer to the 3d. question.—By making the weirs parallel to the direction of the current, so as to make, as much as possible, a right line or fair curve, and sloping the banks, covering the same with fascines and gravel, except on such places as they can be grassed over.

Austhorpe, 28th November, 1760.

J. SMEATON.



On the water-works at Halifax.

To Mr. SIMPSON.

SIR,

INCLOSED you have a sketch of the method which I would propose for laying of the pipes of the intended Water-works at Halifax, and an estimate referring thereto, which I hope will be near the matter, having spent some time in the consideration and forming thereof; however, I would not wholly rely upon my own judgment, but desire that those papers may be overlooked and considered by my ingenious friend Joseph Knight, whose natural sagacity and acquirements in these kinds of affairs will, I am persuaded, lead him to discover and point out such oversights and mistakes as I may have been guilty of, notwithstanding the care I have taken; and I must take this opportunity of desiring, that, though the Gentlemen have thought proper to consult me on this occasion, I may not be considered as any bar to his merit, but rather as jointly concerned.

It may not be amiss, however, to point out the general principle upon which I have conducted myself; and, in the first place, as the town lays very unequal in point of level, and, of consequence, a very great perpendicular pressure will lay upon the pipes, especially towards the lower parts, I have endeavoured to avoid the additional expence, that naturally would arise from proportional encrease of thickness, by taking advantage of such circumstances in the situation, as have a tendency to relieve the disadvantages thereof; and, with this view, I have assigned the bores of the pipes in general considerably less than I should have done, in case the town had been more upon a level, because the declivity has a tendency to force the water through the pipes with greater velocity, and make them give as much water through makes given orifice, as would be done by a larger pipe more upon a level, and with a lesser pressure upon it.

2dly. Confidering that the supply will come from above the head of the town, and that the pipe of conduct, at its first entrance into the town, must carry all the water necessary for the supply of the whole, but that in going lower down it has only the water to convey for such parts as lay still lower; of consequence, the necessary bore of the pipe of conduct will grow less and less the further and lower it goes; but as it is a certain principle in hydraulics, that pipes become stronger in proportion as their diameters are less, when the thickness of the shell of the metal is the same, it follows, that if their bores are dimitthed in proportion their perpendicular pressure is increased, the smaller pipe will be nished in proportion their perpendicular pressure is increased, the smaller pipe will be nished in proportion their perpendicular pressure is increased, the smaller pipe will be nished in proportion their perpendicular pressure is increased, the smaller pipe will be nished in proportion their perpendicular pressure will be to sustain the pressure peculiar as able to sustain its weight of water as the larger will be to sustain the pressure peculiar

thereto: for these reasons, instead of adding to the weight of metal as we go lower down, I have proposed the same thickness for the main all the way, and by diminishing the diameter, and confequently the weight, have added the necessary strength; by which advantage a great weight of metal will be faved, without injury to the main defign. As to the branches, I have proportioned their thickness to the thickness of that part of the main which is upon the same level, regard being had to the difference of their bores; by these means every part of the system of pipes will be equally strong, with respect to the stress that will come upon it. I don't mean, however, that every part is adjusted with a mathematical exactness; for as I have allowed every part to be considerably stronger than what may be barely-called sufficient, that would be not only unnecessary, but by making every yard of pipe of different bore and thickness, would be more unreasonably troublesome in the execution. That that part of the main which lays between the refervoir at the Gibbet, and the back street, I have supposed of the same bore and thickness all the way, for the ease of calculation; but, in reality, I propose it to be considerably wider towards the refervoir, yet, as the pressure diminishes that way, it can be done with the same metal as the calculation supposes.

3dly. Considering, likewise, the inequality of the ground in another view, in cale there should be, at any time, any defect in point of quantity surnished to the reservoir for the fupply of the whole town, it is evident that the lower parts of the town would be first supplied, because the water will naturally run down hill, and accumulate in the lowest parts first, by which means the lower parts would be well supplied, when the upper parts were partially, or scarce at all supplied: and even when the reservoir would furnish as much water as the pipes could take, as the water would issue with much greater velocity from the lower cocks than from the higher; should many of the lower cocks be open together, this would still abate the issuing of the water from the higher, and especially those at a distance from the main, so that while the lower cocks were kept running in this manner, the upper ones would be but faintly supplied; for remedying of which defects, as well as others that would accrue from the fensible effects of the leakage and waste of all the cocks in the town at once, I propose to part the town into two divisions, the upper and the lower, to receive the water alternately: the upper division to consist of all the streets above the Hall end, and the lower division of all below, which will be done by placing a stop-cock upon the main at \* +, and three others at the three principal branches at  $\oplus \Lambda$ ,  $\oplus$  B, and  $\oplus$  C; by which means, the \* cock being shut, and A, B, and C open, the upper division will be served alone: on the contrary, the cocks A B C being thut, and the \* cock open, the lower division will be served, and no part of the upper. And here it must be remarked, that I propose the two streets, called

pr, pm, and not from the main AB, BC; for otherwise, those two streets, with the upper branches dependant thereon, would be perpetually supplied, whereas the supply of every other part of the town would be intermitted, and consequently the distribution unequal.

The equality proposed hereby might, perhaps, be still greater, in case the town was divided into more divisions than two; but as the scheme would be embarrassed with a greater number of branches and stop-cocks, I was unwilling to destroy its simplicity for trisling advantages. Perhaps the division that I have proposed may not consist of an equal value of water-rents; but as this may be adjusted by proportioning the time that each division shall receive the water, I would rather propose this method of preserving the equality, than by taking any other point of division, which, as the town is shaped, I think would not be so convenient.

4thly. Respecting the method of conveyance of the water from the spring to the refervoir; though I am still of opinion it may effectually be done in a gutter lined with clay and gravel; yet, considering that this gutter must be covered, and well secured from evaporation and diversion, I have, upon second thoughts, (at least for the sake of coming to an estimate) supposed this conveyance to be in wooden pipes of sour inches bore, which there is no doubt will answer, and not give the water any ill taste, as the descent from Broadby Laith to the Gibbet is great enough to give the water a rapid current, consequently its time of continuance in the pipes will probably not exceed half an hour.

5thly. I have only further to observe, that I have not included the purchase in my estimate, which, added to the amount thereof, will make a sum much beyond what seemed to be imagined when I was at Halifax; and, on this account, I have been the more minute, and have inclosed a copy of the amount of each particular part of the lead-work, that in case I have inserted or omitted any street which ought to have been otherwise, a proper correction may be made; and also that the whole may be submitted to examination, from whence I flatter myself it will appear that the matter is not exaggerated. And I am, with the utmost respect to the gentlemen promoters of this scheme,

SIR,

Your most humble servant,

J. SMEATON.

P. S. Please

P. S. Please to tell my stiend, Mr. Stansfield, that the improvements I supposed might be made in sulling as well as other mills, when this matter came in question on the Calder, is no longer a matter of theory; and, contrary to the determination of Mr. Banks, that a fulling-mill is a machine so simple, that it is not capable of any farther improvement, a fulling-mill that has been erected from one of my plans, in dry times, goes with less than a quarter of the usual quantity; and in freshes goes with 3 seet 8 inches tail water; though the greatest difference between head and tail water, when the last is most down, in dry seasons, never exceeds 4 feet 6 inches.

### ESTIMATE for the Water-works at Halifux.

		to*	5.	a.
To expences in walling and securing the spring head,	-	30	0	0
To piping from Broadby Laith-spring to the Gibbet, being two miles, to be wood pipe	four			
inches bore, laying and compleating, at 5 s. per yard,	-	880	0	0
To erecting a water-house and reservoir near the Gibbet, -	-	200	0	0
To 653 cwt. of lead piping in the main, leading from the refervoir to Smithy Stake, for	lder-			
work, laying, and making good the streets, at 1/, 41. per cwt.	-	783	12	0
To 931 cwt. in the branches at ditto,	-	1117	4	0
To four large brass stop-cocks and a valve, at 41. each,	-	20	0	0
		3030	16	0
To unforeseen expences, at 10 per cent.	-	303	0	0
				_
		3333	16	0

London, 14th February, 1761.

Place.	Bore,	Thick- nefs.	Length,	Weight.	
			Ch. L.	lbs.	
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bcdb	2		13 00	7.937	
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ghi	13	\$ 7 G	8 62	6,141	
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v E	11	7 6 7_	3 00	3,870	
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R V	1 7/2	1.28	2 60	1,632	
ST	1 ½	T 6	9 20	8,115	
ENOG	13	1	2 40	1,506	
Q_P	11/2	18	3 60	2,808	
HM	11	*	2 17	2,282	
HI	14	78	7 00	6,528	
IKKL	11	78	/ 00	·	C. qrs. Ibs.
			126 53	104,265 =	= 930 3 21
			165 67	177,387	1583 3 7

PROPOSALS for building an engine for raising water it seet from the well or reservoir, into the piece of water in the gardens of Her Royal Highness the Dowager Princess of Wales, at Kew, to be worked by one large or two light horses.

THE following things are supposed to be done at the expence of Her Royal Highness: The drain or gutter, leading from the engine to the Chinese house to be lowered four feet; the ground to be cleared and levelled for the engine to stand upon; the earth to be wharfed up with brick-work; the well cleaned, and the brick-work repaired, where necessary; and, in case it is thought expedient to underpin the groundsill of the shade with brick, the materials to be led from the river to the place, and the labourers to assist in lifting and digging what may be required during the setting up.—The engine to work with an Archimedes screw, 2 seet 8 inches diameter, and 24 feet long; the shade for the horses to be 30 feet from out to out, and the mean diameter of the horse track 24 feet.

This engine to raise 1200 hogsheads in four hours, with one large horse or two light ones, such as have heretosore been used.

A small pump, to be worked occasionally by the engine, for raising water from the gutter to the cistern, in the kitchen garden.

The whole of the machinery and frame-work thereof, with the shade for the horses walk, and a cover from the screw, with a cistern and sluice at the soot thereof, to be completed in the most substantial and workman-like manner, for the sum of one hundred and sifty pounds.

The REPORT of John Smeaton, Engineer, concerning the practicability, &c. of a navigable canal from Wilden ferry, in the county of Derby, to King's Bromley common, near Litchfield; and from thence in several branches, the first leading to Longbridge, near Burstem, the second to Newcastle under Line, the third to the city of Litchfield; and the fourth to the river Tame, at or near Fazeley bridge, near Tamworth, all in the county of Stafford, as projected by Mr. James Brindley, Engineer.

HAVING, in company with Mr. Brindley and Mr. Henshall, land furveyor, in the month of November, 1760, carefully viewed and confidered the tracts of ground through which the canal abovementioned and its branches are proposed to pass, and compared the same with the plans and levels produced by Messrs. Brindley and Henshall; and also viewed the course of the rivers, (Trent and Tame) as well as the several brooks, streams, water-courses, and whatever else seemed principally to relate to the abovementioned project, it appears to me as sollows:

1st. That the waters that are or may be collected into the brooks, at the head of the proposed canal and its several branches, are respectively sufficient to supply the same with water; and that the canal and its branches, as projected by Mr. Brindley, are practicable, and may be executed at the several expences contained in an estimate bearing the same date as this report.

2d. That as the river Trent appears to have few pools naturally navigable, in proportion to its extent, and those of no great length, but on the contrary abounds with shoals, is in many places very winding, in general runs in a shallow channel, and is subject to continued floods; in consequence a new canal will answer the purposes of a navigation, in the present case preserable to carrying the same more generally through the mother river, and which, for a great part of the tract in question, is impracticable at any tolerable expence.

3d. That, in particular, the present navigable part of the Trent, between Wilden serry and Burton, is so much obstructed by shoals and scours, that the purposes thereof would be much more effectually answered by the canal projected by Mr. BRINDLEY.

4th. That the tracts of ground through which the canal abovementioned and its branches are proposed by Mr. BRINDLEY to pass, are well chosen, and for the greatest part well adapted by nature for such a purpose, and as little injurious to private property as the nature of such a work will admit of; Mr. BRINDLEY having judiciously designed the course thereof to pass through a great number of level commons and waste grounds, and, in general, through the most barren lands that could be found in any wise to agree with the course thereof.

5th. That a branch from the canal to Longbridge may be conducted upon a dead level from near the town of Stoke to the town of Newcastle, as laid down in the plan.

6th. That a canal from King's Eromley common may be conducted up the valley of Litchfield Erocks, to the city of Litchfield, but at a very moderate charge, to the tail of Stow pool.

7th. That a canal being conducted upon a level from some proper point of the main canal, at or near King's Bromley common, the same will meet the valley of the Tame, at or near Fazeley bridge; and by inverted locks a communication may be formed, and the navigation may be carried by that river to the borough of Tamworth, the waters being pounded up thither by the mills at Tamworth.

8th. That the branch of the canal, proposed to be carried to Longbridge, is capable of being extended, so as to join the navigable river that falls into the west sea; for it is but a little above two miles from Longbridge, to a meadow which lies between two hills near Harecastle, in which meadow the waters that run into the west sea divide from those that make their way into the east, and which therefore may be called the point of partition, The grounds between Longbridge and this point lie with a gentle declivity, and, according to a level taken by Mr. HENSHALL, this point of partition is elevated above that of Longbridge a little more than 90 feet; but as one third part of this ascent lies within a quarter of a mile of the fummit, and as the ground there appears to be fuitable, a confiderable part of this afcent may be avoided, by a deep cut through the fummit, which will be of a moderate length, as the ground feems of the same quality, and to fall away much in the same manner on the west side as on the east; and as, according to the report of those who know the grounds, particularly the meadows on the west side, are nowhere interrupted by rocks, or other remarkable obstructions, a canal is by confequence as practicable from the point of partition westward, as it is from the same point eastward; and the distance is not near so great to the navigable rivers on the west, as

on the east. It only remains that probable means be shown of supplying this additional canal at the point of partition with water; for if this is done, the lower parts will be supplied of course: In respect whereof it must be observed, that the point of partition lies greatly under the level of the adjacent hills, and consequently the springs issuing from such hills may be conducted thither, and all the water upon the more elevated grounds may be intercepted for several miles round, in order to supply a reservoir in proper place, above the level of the point of partition. These springs will be further assisted by water issuing from the coal-pit drains that now are, and hereafter will probably be multiplied, as the grounds hereabouts abound with coal, the greatest part of which is at present ungot; but should all these resources, in a dry season, prove too little, the navigation may be supplied with water by the help of a fire engine, to return the waters from a lower level, where the collection of springs may at all times be sufficient; so that the water may be used as many times over as may be needful.

77 That from the best information it appears, that the present navigation between Wilden serry and Gain brough is much obstructed by shoals and scours, informuch that in several places, in the common state of the river in dry seasons, there is not above sinches depth of water, and that at such times, without the aid of stashes from Kings mills upon the Trent, and the lowest mills upon the Derwent, the navigation would then be impracticable.

10th. That, for these reasons, the purpose of the canals before mentioned will not be fully and compleatly answered, without an amendment of the navigation between Wilden ferry and Gainsbrough, either by an extension of the main canal from Wilden ferry to the tide's way, or by some other means that may effectually answer the purpose; nevertheless, I am of opinion,

even should the obstructions of the navigation between Wilden serry and Gainsbrough remain as they are; for, notwithstanding those obstructions, a large quantity of goods is navigated up this part of the river with advantage, and if a canal is compleated, on the present plan, to Wilden, it will be still better worth while to conquer the difficulties attending this part, in order to get into a clear and complete navigation, that will carry goods, without obstructions, into the heart of the kingdom, according to the printed plan; and even across the kingdom, if the scheme should take place in its sull extent; and whenever that is the case, it is not to be doubted but means will be sound of rendering the navigation between Wilden serry and Gainsbrough equally perfect with the rest.

may navigate freely upon the new canal, I am of opinion with Mr. BRINDLEY, that the canals ought to be about 8 yards wide at the water line; and that the new canal may be of a fuitable depth, when the obstructions below Wilden are removed, the same ought to be 2 feet 6 inches deep of water upon the fording-places, which ought to be shoalest, and 3 feet or 3 feet 6 inches in other places, to allow for mud, and sufficient freedom for the vessels; and this depth will be of advantage, notwithstanding the want of depth of water below, because the loading of two vessels from Gainsbrough may be put into one at Wilden, and the loading of two vessels at Wilden brought in one from above.

13th. That the lock gates being made water tight, as they are capable of being made, no mill can be deprived of any water. Farther, that one lockful to each boat, which on exact calculation is found to be a very inconfiderable quantity, in proportion to what is necessary to work a mill for 24 hours; the evaporation from the surface of the canals, and leakage through the banks into the back drains, scarcely deserve mention, with refpect to their effect on the mills. As to fisheries, they cannot in any wise be affected, because the waters in the canals being nearly stagnant, and closed by the lock gates, no fish can pass either way.

14th. That the publick road being supplied with sufficient carriage bridges, the water courses with underground passages, the communication between commons and private properties by a sufficient number of fording-places, well paved and sloped, and nowhere above 2 feet 6 inches deep, and the banks, whenever the water of the canal is even with or above the natural soil, to be surnished with sufficient back drains, to convey any leakage of the water that may happen, to its proper and natural place of discharge; I say, things being thus provided for, public and private roads, all necessary communications between grounds and water courses will not only be preserved, and the grounds themselves freed from damage, but, on the other hand, many lands will be greatly benefited, by having plenty of good water for cattle, &c.

Austhorpe, 11th July, 1761.

J. SMEATON.

General ESTIMATE for making the canals and works for compleating the navigation and branches referred to, in Mr. Smeaton's report, upon principles of estimation settled between Messis. Smeaton and Brindley.

1st. To making the main canal from Wilden Ferry to King's Bromley Common, being in length	£.	3.	d.
25 miles, the perpendicular ascent 110 feet, with 19 locks thereon,	32,054	10	0
2J. To making the great western branch, from King's Bromley Common to Longbridge, be-			
tween Burflem and Kenvenstle under Line, being in length 304 miles, perpendicular ascent			
1664 feet, with 28 locks thereon,	45,884	15	o
3d. To the small branch out of the last, proceeding from Stoke to Newcastle, being in length	12.		
34 miles, upon a dead level, without a lock,	3,806	6	O.
4th. To making the Litchfield branch, from King's Bromley Common to the tail of Stowpool			
near Litchfield, being in length 21 miles, perpendicular ascent about 18 feet, with 3 locks			
thereon,	3,995	Q	Q
5th. To compleating the above into Litchfield mill pool, being about half a mile, and per-			
pendicular ascent about 30 sect, with 5 locks thereon,	3,039	18	0.
6th. To making the Tamworth branch, from King's Bramley Common to Fazeley Bridge near			
Tamworth, being in length 10 miles, upon a dead level, without a lock,	9,431	12	-
7th. To compleating the above by a cross canal into the river Tame, being in length half a	2.13		
mile, perpendicular descent 16 seet 10 inches, with 3 locks thereupon,	1,995	12	0
	-		
	100,198	2	

Austborpe, 11th July, 1761.

J. SMEATON.

#### THE RIVER WEAR.

The REPORT of J. SMEATON, concerning the fituation of the first lock upon the river Wear.

HAVING, in obedience to the order of the Commissioners, at their last meeting on the 2d day of May, 1761, re-examined, as well the situation staked out by me in November last, as the situation lately proposed by the Gentlemen Coal Viewers, who viewed and marked out the same 176 yards higher up the river than the sormer; and having carefully examined the river in both places, and also at intermediate distances, I am humbly of opinion as sollows:

1st. That the erection of a lock at the place marked out by me in November last, cannot have the least tendency to prejudice the coal works underneath; for though the workings underneath are ever so irregular, and though a thrust should have been brought on 2 pillars 30 yards 'to the north of the lock, yet while those pillars are capable of supporting the river Wear, they are capable of supporting the lock. Nor will the placing of a lock there in any wife tend to weaken the body of folid matter interposed between the bottom of the river and the bed of coal; for the sill has been found in the bottom of the staples at 21 feet from the surface of the ground, and it may be necessary to fink the foundation of the lock 24 feet below the same surface; yet as the staples are sunk 18 feet, or thereabouts, more northward than the utmost limits of the lock wall; and fince it appears that at the verge of the water, and within the river, the fill lays as low, and in many places much lower than the intended foundation, there does not appear to be any occasion to sink into the sill at all; and yet in case there should be occasion to cut half a foot, or even one foot on the north side, into the sill, by way of bringing the same to a level, (the sill appearing from the staples to rise with the hill towards the north) yet as this will be replaced with matter much more compact and impenetrable to water than the fill itself, it is not easy to conceive that this can in the least prejudice the resistance of a body of matter 12 or 15 sathom in thickness, being so much down to the workings of the 5 quarter coal.

2dly. That it is practicable to build a lock at the place marked out by the Gentlemen Coal Viewers, 176 yards higher up the river than the former; but that such situations will be attended with the following additional disadvantages.

If. It appears, that the fill laying at the last mentioned place, a medium, if seet lower than the foundation of the lock, the carrying the soundation one soot and a half lower than necessary, will not only be attended with a considerable charge, but being quicksand down to that depth, the drainage of the water, and securing the sides of the lock-pit till the bottom is finished, will be much more difficult and expensive also. And lastly, as there will be necessity of making a channel for the passage of the vessels on the north side, into the lock, from the tail of the lock, as proposed in its former situation, it will therefore be necessary to dredge the whole distance of 176 yards; and not only that, but to secure the side of the channel next the river with a proper sence, to prevent its being silled with the silt of the river upon the sirst flood; and as this is a work capable of estimation, I have hereto annexed an Estimate thereof.

Durham, 2d June, 1761.

J. SMEATON.

ESTIMATE for the probable expence of clearing the channel of the river Wear 176 yards, being the distance of the situation of the first lock, as proposed by the Gentlemen Coal Viewers, above the situation as staked out in November 1760, by John Smeaton.

	Lo	s.	d.
To 176 yards of water-tight wearing, = 41. tos. per yard,	79z	0	O.
To fixing a temporary crofs dam, at the tail of the Wear, and taking the same away,	10	0	0
To drainage of the water while the filt is getting out, supposing 30 days, at 6s. 8d. per day,	10	0	0
To getting out 1760 cube yards of matter, at 6d	44	0	0
	856	0	0
To unforescen accidents at 10 per Cent.	85	12	Q
			_
	941	. [2	0
	-		_

N. B. The 176 yards of water-tight dam is intended to be executed with oak, in a durable manner, so as to remain a sence against the silt of the river.

D 2

General ESTIMATE	for compleating the	first lock and dam,	at or near Jackson's,
	near Harraton, upo	on the River Wear.	

	L.	J.	d.
To clearing Biddick Ford, and two other shoals between that and Mr. Lambton's engine drain,	500	0	0
To wearing and dredging 176 yards from the bottom of the caunch below L. s. d.		4	
Jackson's Ford, up to the tail of the lock, as per former estimate, - 941 12 0			
To probable expence in the foundation of the lock at Jackson's Ford, supe-			
rior to that in its first intended situation, 258 8 0			
	1200	0	0
To expence of building the lock in its first situation, 900 0			
To ditto of the dam adjoining, 600 0 0			
To cutting the ground drain of the water and temporary dam to both, at			
least, 500 0 0			
	2000	0	0
Expence of the navigation from Briddick Ford to new bridge,	3700	6	10

N. B. 1st. The expence of the machines, shops, utensils, &c. together with the necessary materials for beginning the work, will be at least 1000% and if the work goes on no further than the first lock, there will be at least 500% lost by the articles just mentioned, which otherwise would serve for the whole.

### THE RIVER CALDER.

Comparative ESTIMATE for carrying on the navigation of the river Calder, by means of a long cut from the figure of 3 lock at F, to above Dewsbury low ford at H, and of carrying it partly by the river and partly by 3 short cuts as in the general plan.

### ESTIMATE for a mile of cut.

	L.	3.	d.
To 14 acres of land at 50 l. per acre,	700	0	0
To cutting, at medium, 6 feet deep, 16 feet wide at bottom, and 36 at top, at 3 d. per yard			
cubic,	381	7	0
To fodding and batting down the banks, and fowing them with hay-feeds, at 21. per rood,	41	16	10
To extra work in forming 8 passing places, at 5 l. each,	40	0	0
To 14 quarters of hay-seeds, = 71. per quarter,	4	18	0
Expence of land, cutting, &c. per mile, c	1168	I	0
ES	TIM.	AT	E

### ESTIMATE for the navigation by the long cut.

		£.	J.	di
To 21 miles at 1168 l. 11. per mile, land and cutting,		2628	2	0
To extra work in digging two lock-pits, at 30 l. each,		60	0	0
To 3 carriage bridges of wood, at 60 /. each,		180	0	0
To 3 tunnels for draining, at 10/. each,		30	0	
To 1 lock building, at 600/. and 1 ditto at 400/.		1000	0	0
To 1 low dam at the head of the cut,		300	0	0
To extra work in banking near Millbank Quarry, and cutting through a rising	ground near			
the Warren House,		150	0	0
		4348	2	0
To contingencies on the above articles at 10 per Cent		434	16	0
	Total	4782	18	0

### ESTIMATE for the navigation as by the general plan.

To 3 of a mile of cut, at 1168 /. per mile,	-	-	-	-	-	-	1022	0	0
To extra work in digging 3 lock-pits, at 40	l. each.			-	-	-	120	0	0
To 3 tail-bridges for the locks, at 20 1. each				2	-	-	60	٥	٥
· ·			-				10	0	0
To 1 tunnel for drainage, at 101.				_	_	_	1600	0	0
To 2 locks building at 600 /. and 1 at 400 /.							800	0	0
To 1 dam at 500 l. and 1 ditto, at 300 l.	1	•					- 100		0
To extra expences in croffing the Calder,	<u>-</u>	1.0.1	41		-la	Lanta	100	·	ď
To extra expence in removing the new mill	cloughs,	and letting	g bries	prevent	une	DORES			
going over the dam,	-	~	~	-	-	-	100	0	0
80008							3812	0	0
					3	-	762	8	0
To contingencies on the above articles, at a	to fer Ge	nt.	•	=	2				
						Total	4574	8	0

### TETNEY HAVEN NAVIGATION.

The REPORT of John Smeaton, Engineer, concerning the practicability, &c. of a scheme of navigation from Tetney Haven to Louth, in the county of Lincoln, from the view taken thereof in August, 1760, as projected by Mr. John Grundy, Engineer.

HAVING carefully examined the scheme of navigation proposed by Mr. John Grundy, for making a navigable canal from Tetney Haven, to the upper end of Avingham out-sen; and from thence to join the river Lud, or Louth river, between Ringer's drain and Avingham mill; and from thence, partly by the course of the river, but chiefly by a new canal, up to new bridge, at or near the town of Louth; and having carefully compared the said scheme with the lands through which the aforesaid navigation is proposed to pass, and also examined, as well the principal water-courses, eau-moats, and out-salls, as the havens and communications with the sea and river Humber, which relate to the above said scheme, I am of opinion as follows:

- the That Tetney haven is the most proper out-fall for a navigable canal, as being both safest and deepest, and affording a communication with the inland navigations of Yorkshire and the Trent, for slat-bottomed barges, without going to sea, which, at some seasons of the year, would be dangerous or impracticable.
- 2d. That the course of the intended canal, as laid down in Mr. Grundy's plan, from Mr. Young's warehouse, near Tetney haven, to its junction with the Louth river, between Ringer's drain and Avingham mill, is the most eligible position, both for the purpose of navigation and drainage, as passing in general through the lowest grounds.
- 3d. That the rest of the intended navigable course, from the junction of the canal with the river as aforesaid, to New Bridge, near the town of Louth, as marked out in the said plan, is also very proper, and does not seem likely to be attended with any particular prejudice to the owners of the adjacent grounds, more than what is inseparable from the nature of the undertakings of this kind.
- 4th. That the owners of the low grounds, that are liable to be affected by the Tetney river, will, in particular, receive great benefit from this undertaking; because,

5th. The

5th. The water of Tetney river being received into the navigable canal before it meets the fea stuice or lock, as the water of this canal is, by the said proposed scheme, to be kept constantly lower by 1 foot than low water mark of the Tetney river, under Sheep's bridge; it follows, that the surface of Tetney river will, at its out-sall into this canal, be kept at least one foot lower than it could be by placing a sea sluice at or near Sheep's bridge upon the present course of the river.

6th. I am of opinion, that the carrying the navigation up the Tetney river further than Sheep's bridge, will no way contribute to the more effectual drainage of the Tetney lands, and will carry the canal confiderably out of its due course; but that a navigation for lighters and small vessels may be separately made up the Tetney river to Tetney, at a small expence.

7th. That the surface of the water of the canal, being kept one soot lower than the point of low water at Sheep's bridge, will be lower than the surface of the water in all the drains that it will intersect; and consequently, that the water of those drains being turned into the canal, will afford a means of draining those lands more effectually, or may occasionally be kept up at their present level by small shuttles, or stops, near the side of the canal.

8th. Where the passages for waters from springs, for watering grounds and other purposes, are intersected by the intended canal, and are desired to be continued in their present course, they may be continued by subterraneous passages or tunnels, as has already been observed in Mr. Grundy's Report.

9th. That the principal conveyance of spring water next to Tetney river, appears to be that of the North Coates Fleet, the surface of which lays higher than the surface of the intended canal, and therefore will discharge itself into the same; consequently, if there should be any objection from Tetney, against supplying the navigation in dry seasons from their river, such supply may be had from North Coates Fleet, or other sources, having communication with the canal upwards.

that the sea lock ought to be provided with ebb-gates, or gates pointed landward, as well as seaward, that the water may be retained in the canal to its due height, and to enable the vessels to pass at all times when there is depth of water without the sea-lock; it also appears to me, that the purpose of the lock will be as essectually answered, by taking in one vessel at a time, as by taking in two.

dance of one parish should contribute to the defects of another, this canal would be the best means of performing it; for a part of the water of North Coates Fleet, or Tetney river, being admitted into the canal, all those grounds contiguous, or which might be brought to communicate with the canal, quite up to Avingham out-sen, might, by proper drains, be supplied with spring water.

12th. That according to the modern practice of building locks, they are capable of being made and preserved water-tight, wherever this circumstance is necessary.

13th. That according to this scheme, no water will be turned away from Ringer's drain, and the eau-moats, except what is necessary to fill a part of the first lock upon the canal near the upper end of Avingham out-sen.

1.4th. That on the 7th day of August, 1760, after the driest season that has been known in the memory of man, I carefully examined the discharge of water by the Louth river in 24 hours, at Thorold's mill, being the first below the new bridge at Louth, and compared the same with the discharge at Avingham mill, and sound the quantity such as to fill the said first lock, near the upper end of Avingham out-sen, to the height required for the passage of a barge 200 times in 24 hours. So that, even in the driest seasons, the quantity of water expended by the navigation will be so very inconsiderable, in proportion to what will still remain, that the difference will be quite insensible to the occupiers of lands.

15th. That there is a possibility that even this inconsiderable loss of water may be totally prevented in scarce water times; but at an expence to the undertaking which so inconsiderable a quantity does not seem to merit.

16th. That the course of the river from the place of junction of the canal therewith to the town of Louth, being narrow, crooked, and generally shallow, with level meadows on one or both sides, and scarcely any part of it in a navigable state; I apprehend it will be more eligible and less expence to dig a new canal, with locks upon the same, at proper distances, than to pursue the old course of the river; and that the scheme above referred to, is very proper for this purpose.

17th. That the rife of the river, from the place of junction of the canal with the river, as aforesaid, to Keddington old mill, is very gentle, being in length about 2.3 miles, and

and rife about 24 feet, according to Mr. GRUNDY's furvey; from thence to a meadow little below the leather mill the ascent is more sudden, being 11; feet in three quarters of a mile; and from thence to the new bridge at Louth still more, being about 21 seet in the same space.

18th. I am therefore of opinion, that the distance of three quarters of a mile from the leather mill, to the new bridge at Louth, will be, in proportion to the distance, the most expensive part of the undertaking; but that a considerable sum will be saved by terminating the navigation at Kiddington old mill, to which place it may be brought on very moderate terms.

Austhorpe, July 14, 1761.

J. SMEATON.

GENERAL ESTIMATE of the expence of making a navigation from Tetney Haven to Louth, according to Mr. GRUNDY's plan.

	For barges with ca- nals wide enough for two to pass in all	For barges with ca- nals for one, with passing places.	For lighters drawing 2 feet water.
From Terney Haven to the new bridge at Louth,	places. L. 15,590	L. 13,686	£. 10,884
From Tetney Haven to the meadow below the leather mill,  From Tetney Haven to Keddington old mill,	12,968	11,241 9,481	8,931 7,589
From Tetney Haven to the top of Avingbam	7,853	6,566	5,312

N. B. In the above estimate the expence of procuring an act of parliament is not included. The marsh land is estimated at 101. and the meadow at 201. per acre; the ground covered is reckoned at half value, or, what is the same thing, at half quantity: the quantities to be purchased are as under, so that whatever alteration there may be in the price now supposed, the difference may be applied without affecting the other articles.

		z ba	arge canal.		1 barge canal.					canal for lighters acres.			
			acres.			acres.			-		40		
Marsh lands,	2	•	57	•		45 <sup>1</sup> / <sub>2</sub>		-			221		
Meadow land,	-	-	321	-	-						623		
	Total	acres,	891			71長							
Austhorp	. Inh	v #1.	1761							J. Sm	EATON.	he	
Andrea L	, jui	,	7,211		E							iie.	

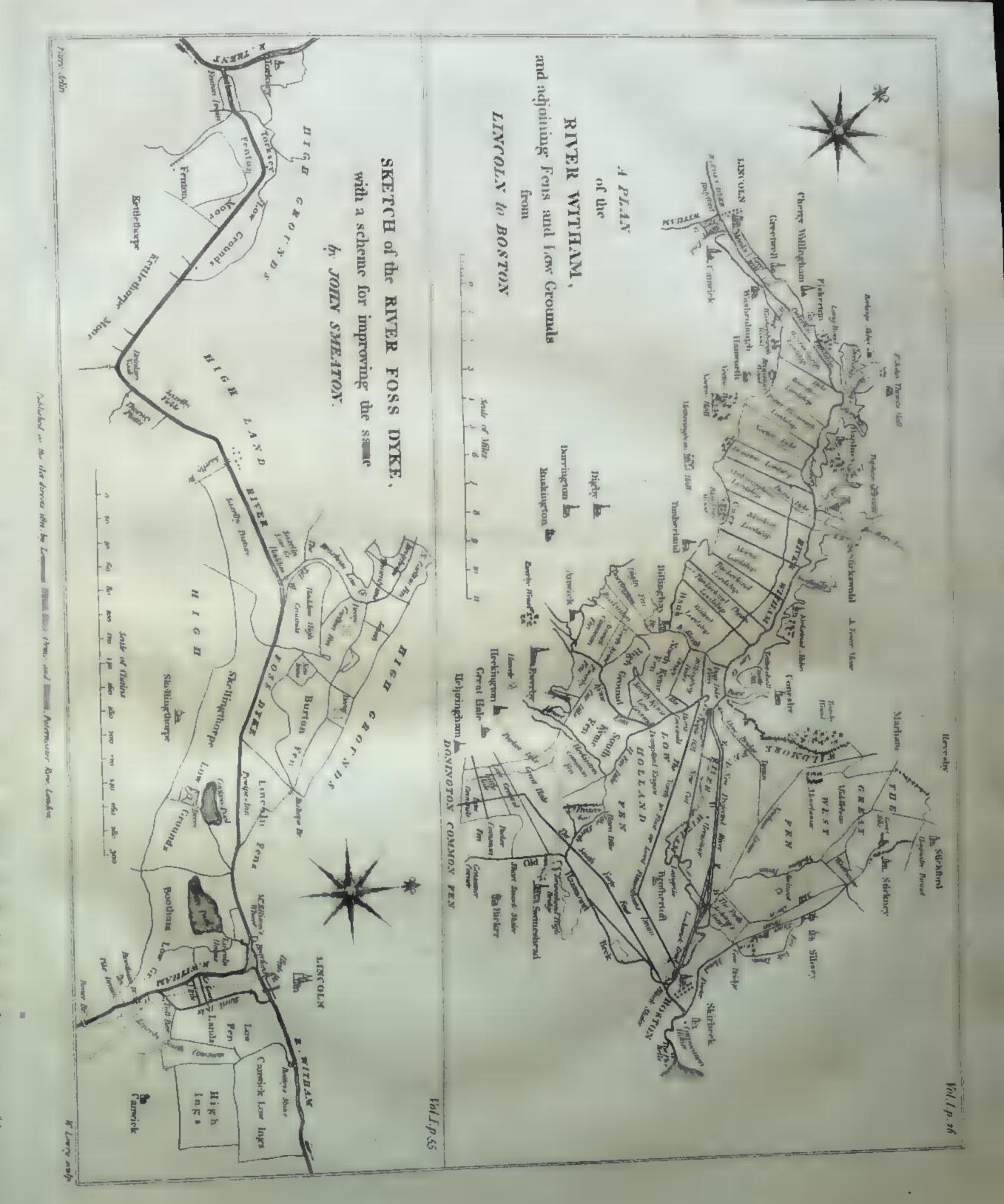
#### RIVER WITHAM.

The REPORT of Messers. John Grundy, Langley Edwards, and John Smeaton, Engineers, concerning the present ruinous state and condition of the river Witham, and the navigation thereof, from the city of Lincoln, through Boston, to it's outfall into the sea; and of the sen lands on both sides the said river: together with proposals and schemes for restoring, improving, and preserving the said river and navigation, and also for effecting the drainage of the said sen lands: to which is annexed a plan, and proper estimates of the expences in performing the several works recommended for those purposes.

### INTRODUCTION.

grounds of the several lordships following, on the south side thereof, viz. Lincoln, Canwick, Washinborough, Bransson, Potter-Hanworth, Noston, Dunston, Metheringham, Elankney, Marton, Timberland, Timberland-Thorpe, Walcot, Billinghay, Billinghay-Dales, and Dogdike, to Chappel Hill; and on the north side through the sow grounds of Monks, Greetwell, Willingham, Fiskerton, Barlings, Stainfield, Bardney, Southrey, Tupholm, Bucknall, Horsington, Stixwold, Swinesike, Woodhall, Thornton, Kirkstead, Tattershall, and Coningsby: and from the said Chappel Hill it runs, in a very crooked and meandring course, betwixt the large and extensive sens called Holland Fen on the south, and Wildmore and West Fens on the north, to Room's Hall, and from thence, through some inclosures, to Boston, and from Boston, through the High Marshes, into the great bay called Metaris Estuarium. The distance from Lincoln to Boston, by the old course of this river, is about 43 miles.

This river has formerly been a very good navigation from it's outfall at the Scalp to Boston, (which is about 4 miles) sufficiently capacious and deep to navigate large ships into the town, and from thence to convey barges, keels, and other vessels, to Lincoln, almost at all times in the year; and a very extensive and advantageous branch of commerce has, till of late years, been carried on by the said river, to the great benefit and advantage, not only of the city of Lincoln and town of Boston, but also of the several towns and villages adjoining upon, and contiguous to it, through an extent of country for many miles in length and breadth.



It was also, when in the aforesaid state and condition, the mother river and outsall for the drainage, not only of the low grounds and sens aforesaid, but also of the low grounds of North Kyme Fen, South Kyme Fen, Hart's Grounds, Great and Little Beets, Rakes, Heckington Fen, Lady Frazer's 600 acres, Ewerby, Howel, Asgarby, Great and Little Hales, Brothertost, Anwick, Ruskington, Dorrington, Digby, Mareham, Hund'e-House, Revesty, Middleham, Moor-House, Meer Booth, Hermitage, Newbolme, West-House, Langrike, Frith Bank, Langworth, Swinecote, Stickford, and Stickney; and also of many other low grounds and sens lying more distant and remote therefrom, (but having their outsalls for drainage into it) containing in the whole, by estimation, upwards of 100,000 acres.

This once so flourishing river and country have, for many years last past, been falling into decay, by the banks of the said river being suffered to become ruinous, and incapable of sustaining and confining the water in times of high country floods, so that those flood waters, which were necessary and used heretosore, by their velocity and weight, to cleanse out the sand and sediment brought up by the tides, have been, and now are, suffered to run out of their ancient and natural course, and expand over the adjoining sens and low grounds, whereby those sands, for want of a reflowing power of adequate force to carry them back, have now so much choaked up the haven from Boston to the sea, that for several years last past the navigation thereof has been lost for shipping, and it is now become even difficult for barges of about 30 tons burthen to get up to the town in neap tides. And for several miles above the town of Boston the said river is totally lost; insomuch that it's bottom is, in many parts, some seet higher than the adjoining low grounds, and the scite thereof converted into grazing and farming purposes.

This mischievous effect has not only been destructive to the navigation of that river, but also to the drainage of the aforesaid vast tracts of sens and low grounds, by reason that many of the mouths of the inward drains, dikes, and sewers, which should have their outfalls into this river, are totally landed up, and lost, and have not run at all for many years into it; and the sew that have their outfalls so low as Boston, and below it, are nevertheless, in all dry seasons, so much choaked up and obstructed, that the said sens and low grounds must be, in some parts, considerably under water, before said sens and low grounds must be, in some parts, considerably under water, before they can have vent through their outfalls into the said river or haven, whereby the slood-waters lye so long stagnant thereupon, as to destroy the herbage thereof, and render shown not only useless and unprofitable, but also extremely noxious and unwholesome to the adjacent inhabitants.

To find out proper and necessary expedients to improve this river and sens, surveys and levels were taken, some years ago, from Wiberton Roads to Lincoln, not only along the course of the said river, but also on the adjoining sens and low grounds, to compare their different surfaces, both with respect to the said river and their outsalls to sea; in consequence of which a scheme was formed, and published in the year 1744, by Messis. Grundys, Engineers, recommending such expedients as, to them at that time, appeared proper for effecting the above desirable purposes; upon which, several meetings have from time to time been held, to consider this and other schemes, and many clauses were prepared for a bill, particularly at a meeting held at Lincoln, in November, 1753, and others subsequent thereto.

In the year 1760 Mr. Langley Edwards was employed to make views of the premises in question, and since then Mr. Grundy, the son, has resurveyed the river and sens, and both have made their several reports thereupon; which said surveys, levels, resolutions, and reports being duly considered, and a fresh view taken of the river and sens in October, 1761, by Messrs. Grundy and Edwards, in conjunction with Mr. John Smeaton, Engineer, we, the said John Grundy, Langley Edwards, and John Smeaton, are jointly of opinion as sollows, viz.

### REPORT.

In the first place it appears to us, that from the great tendency of this river to filt, and the great advance the same has made in the space of 20 years, that in all human probability within the compass of a sew years more, not only the outsalls of the present effective drains near Boston will be totally lost, but the whole river landed up, unless sufficient measures are speedily taken to prevent it; and the most eligible means for so doing, we conceive, will be to make and preserve a mother river, of sufficient depth and capacity, to effect a general drainage of the several sens and low grounds aforesaid, and also to restore this lost navigation, from the sea through Boston to Lincoln, and into the Brayford Meer, (which has a navigable communication through the Fossdike with the river Trent) upon the following principles, and by the following methods, viz.

- 1st. That the new proposed river be made in the shortest direction that can be, consistent with the lowest surface of the country, considered in a medium proportion, and most convenient for receiving the waters thereof.
- 2d. That its dimensions be such as to be capable of receiving and discharging, not only all the upland waters, but also all those of the several branch rivers and drains that fall into it.
- 3d. That its banks be made of sufficient strength and height to confine the stood waters within them, and to force them down to sea, without overslowing the adjoining sens and low grounds.
- 4th. That its bottom be made with a regular declivity from Lincoln to the sea; which, according to the levels, will be at a medium near 5! inches per mile.
- 5th. To collect all the living waters into this new river that can be obtained, by fouring out and imbanking all fide rivers, rivulets, and brooks that bring down fuch living waters out of the high country into it, in order to obtain a reflowing force that shall be capable of driving out such matter as is left by the tides, by which means only the outfall below can be preserved open and clean.
- 6th. To stop the tides from flowing at all into this new river, that its depth and dimensions may be preserved.
- 7th. That this work shall be so constructed, that navigation may be carried thereon so, as in no wife to interfere with, or prejudice the drainage.
- 8th. That the necessary works be constructed to retain the fresh water, to be made use of as occasion shall require, for the well watering the said sens and low grounds in dry seasons for the use of cattle, &cc.

And lastly. That no salt water be admitted into the mother river, or drains, above Boston, by means of the proposed navigation.

## The SCHEME for the Drainage.

Bridge; and we recommend a piece of ground, commonly called Harrison's four acres, at (A) (see the plan for that purpose), the floor whereof to lie level with low water mark at Wibberton Roads, and its neat capacity or clear waterway to be 50 feet, with three pair of pointing doors to the seaward, to shut with the flow of the tides, and drop or draw-doors on the land side, to be shut occasionally, to retain fresh waters in dry seasons; the top of these draw-doors to be gaged to such a height, as to retain the water of the river, not higher, at ordinary seasons, than 2 feet below the surface of the lowest lands that drain therein.

as straight a direction as the nature of the ground will admit of; so feet broad at the top, 50 feet broad at the bottom, and 10 feet deep: and from the said place at, or near Anthony's Gowt, to make a new cut (in as strait a direction, also, as the nature of the ground will admit of) through Wildmore Fen to Chapel Hill (C), at a medium, 66 feet wide at top, 50 feet wide at bottom, and 8 feet deep. The earth coming out of this new river to be disposed of in forming banks, which are proposed to be set 40 feet distance from the Brink of the river.

3d. The river, from the upper end of this new cut, at Chapel Hill, to Lincoln, is proposed to be continued in its present course; but the shallow parts thereof to be scoured out and deepened, where necessary, so as to be every where of the following dimensions at a medium, viz.

For three miles and a half above Chapel Hill, 60 feet broad at the top, 40 feet broad at the bottom, and  $5\frac{1}{2}$  feet deep below the present bottom. From thence to Washingborough lordship, above Branston Dyke, (being about  $12\frac{1}{2}$  miles) this river (having the waters of feveral rivulets and brooks to receive within those limits) should be 40 feet wide at the top, 30 feet wide at the bottom, and 2 feet deeper than its present bottom, at a medium. From hence to Stamp End, in Lincoln, (being about 10 miles) to deepen the shoals in the old river, so as to be 30 feet broad at the top, 24 feet broad at the bottom, and  $2\frac{1}{2}$  feet deeper than they now are on an average.

4th. To make and crect one waggon bridge at (D), and two horse bridges, (E and F), with necessary gates and sences for continuing the roadway and other communications, and for dividing the Wildmore and West Fens from Holland Fen.

5th. To fcour out and imbank Kyme Eau, from Dampford fluice to the river, or so much further as may be found necessary, so that its banks may be 30 feet seat, 6 feet at the top, and 6 feet high.

6th. To scour out Tattershall Bane, from the mouth thereof to Dickinson's engine, and repair the banks thereof, so as to be 30 feet seat, 6 feet at the top, and 6 feet high.

7th. To scour out and imbank Billinghay Skirth, from the Witham to Billinghay Town, so that its banks may be of the same dimensions as the former; and also to scour out and imbank the Skirth, from Billinghay Town to Kyme causeway bridges, so as to be of proportionable dimensions, for draining the low grounds above the said causeway.

8th. To scour out Barling's Eau, from the river to Barling's Abbey, and repair the banks thereof, so as to be 15 feet seat, 5 feet at the top, and 5 feet high; and also to dike out and embank Stainfield Beck proportionable to the former.

9th. To scour out and imbank Dun's Dike, from the river Witham to the Carr Dike, (or instead thereof to reinstate the Car Dike, and turn its waters therein,) so that its banks may be 15 feet seat, 5 feet at the top, and 5 feet high.

10th. To scour out and imbank Noston Dike and Hare's Head Drain, from the river to the Carr Dike, so that its banks may be 12 feet seat, 4 feet at the top, and 4 seet high.

11th. To scour out and imbank Washingborough Beck, from the river to the Carr Dike, of the same dimensions as the last.

12th. To scour out Tupham Dike, Bardney or Tilehouse Beck, Southery Eau, and Stix-wold Beck, and imbank the same proportionate to the slood waters they bring down.

N. B. Lodowick's Gowt will be wanted for discharging the river waters during the execution of the work.

And, for the more certain drainage of Wildmore and West Fens, a new cut and sluice, to supply the place of Anthony's Gowt, be made and erected by the side of the said new proposed

proposed river, and that the floor thereof be laid as low as the bottom of the said river.

When the works above recommended are put in practice, and have had the necessary time to produce their effects upon the out-fall, we are of opinion, that the surface of the water in the New River will be capable of running at least 4 feet lower at ordinary seasons, than at present it can do, and consequently that not only all the lands lying immediately thereupon will be put into a condition of effectual drainage, but also such parishes which at present drain by engines into Holland Fen, or into the several sewers bordering thereupon, and will likewise be of service in affording a more ready discharge of the downfall waters from the lands lying still surther from their out-fall.

## The SCHEME for Navigation, viz.

of navigation, and one pair of doors pointing to seaward, to keep out the tides.

2d. Upon mature consideration, and comparing the advantages and utility with the increase of expence, we are of opinion, that locks are greatly preferable to staunches, though the expence of the former will be considerably more than the latter. We therefore propose to erect three locks in proper places, by the side of the mother fiver, betwixt the sea sluice and the city of Lincoln, to retain the waters therein for the purposes of navigation in dry seasons (which at the same time will be subservient to the watering of cattle) and one above Sincil dike in Lincoln, to communicate the navigation of the Witham with the Fossdike; but that the faid locks may not be prejudicial to drainage in wet seafons, the three former are to be so limited in their height, that they shall not retain the waters of the main river any higher than within two feet of the natural furface of the lowest grounds above them; and the weirs or wastes appearaining thereto, shall be composed of flood gates, which together shall be of the same capacity with the river, in the respective parts where such locks are to be erected, and the latter (proposed to be erected above Sincil dike) shall be limited to such height, as not to pen the waters higher than the present natural staunch at Brayford Head, and that a waste or weir be erected at the upper mouth of Sincil dike at G, at the same level with this look, so that no prejudice may be occasioned thereby to the present state of the Fossike navigation, or to the low grounds above Lincoln.

3d. For the careful and fafe management of the locks, and that the waste gates may be at all times opened upon the approach of any flood, or when the river is overcharged with water, a dwelling house is proposed to be built against each lock, and a watchman to be fixed in each to take care thereof.

4th. To deepen the bed of the river, betwixt staunch and staunch, sufficient for the purpose of navigation, which at a medium will be about 13 inches, which done will make 3 feet navigation.

5th. To make proper halingways for men and horses on the banks and forelands of the said river, and that no damage may be done thereby, proper gates, bridges, styles and sences be put down betwixt property and property, through which the said halingways may lead.

An ESTIMATE of the expences that will probably attend the execution of the foregoing proposed works, viz.

#### The SCHEME for drainage.

P Carried over	11023	15	0
The forelands and cover will be 491 acres, which, at 51, per acre, is	246	5	0
The commons to be cut through will contain 22 acres, which, at 101, per acre, is	220	0	0
The forelands and cover of the banks will contain about 131 acres, which, at 151 per acre, is	202	10	
to			
The inclosed land to be cut through will contain about 6 acres, which, at 30%, per acre, comes	180		a
cost about 5s. per stoor (or 400 cubical feet) and comes to	01/5	•	0
each fide, and laid in bank fashion, and on account of the great depth of the said cut, will	6175	0	0
which, as the earth is to be barrowed to the diffance of 40 feet from the brink of the river on			
at a medium, will contain 321 floors in a rood, and for the whole length 24,700 floors,			
to the rood) so as to be 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep			
To making the new cut from this fluice, to or near Anthony's Gozot (being 760 roods at 20 feet			
three arches to contain 50 feet next waterway, the fea and land doors of oak, &c. &c.	4000		
dovetail and bearing piles, braces and tyes, with a superstructure of brick and stone, with	1000	0	D
is 3 feet 1 inch and 9 parts lower than Lodowick's Gozul) with a timber floor, supported by			
The sea sluice near Boston to be laid level with the low water mark at Wibberton roads (which	4.	٠,	Par it
on a di D d as he laid level with the law water made at Wilheston roads (which	L	s.	d.

	£.	\$.	d.
Brought over	11023	15	0
To taking away the old banks, and cutting across the old river	200	0	Q.
To erecting a new fluice at Authony's Gowt, and making the communication cut	600	0	9:
To erecting a new cut across Wildmore Fen, from or near Anthony's Gowt, to Chappel Hill (being To making a new cut across Wildmore Fen, from or near Anthony's Gowt, to Chappel Hill (being			
10.0 monde) 66 feet broad at the top, to feet broad at the bottom, and 8 feet deep on an			
average, will contain 232 floors in a rood, and for the whole length 42873,6 floors, which,			
at 4s. pe. floor, comes to	8574	14	S
The land to be cut through will contain 56 acres of common fen land, which, at 10% per			
acre, comes to	560	0	0
The forelands and cover of the banks will contain 136 acres, which, at 5% per acre, comes to	680	0	0
To facuring out three miles and a half above Chapfel Ilill, so as to be 60 feet broad at the top,			
40 feet broad at the bottom, and 53 feet deep below the present bed, will contain 134 noors			
in a rood, and for the whole length (which is 924 roods) 12705 floors, which, at 41. per			
floor, comes to	2541	, 0	0
To diking out the old river where necessary, and imbanking the same from thence to Lincoln,			
being in length 22 miles, which, being estimated at 150% per mile at a medium,			
comes to	3375	0	0-
To erecting a waggon bridge over the new river, in the road from Langrike Ferry to Horn-			
calle, and two other bridges for communication of the cattle for the use of the commons,			
and to making good the fencing betwixt Wildmore and West Fens and Holland Fen, about	1000	0	0
To repairing Lodowick's Gowt, and making proper cuts to discharge the water during the	1150	^-	0
work, leaking out water in the reaches, &c	1400	0	0
To materials of barrows and planks, tressells, gang ladders, engines, and other utenfils, &c.	1200	0	0
and carriage of them to the work	1200		_
To scour out and imbank Kyme Eau, from Dampford Sluice to the river, and repairing the	1000	0	0
banks thereof according to the scheme			
To ditto of Tattersball Bane, of the same dimensions as the last, from the Witham to Dickin-	300	0	Q
fin's Mill Rillinghay Torum, and from thence to Kyme	- 1		
To ditto of Billinghay Skirths, from the Witham to Billinghay Town, and from thence to Kyme  Coulerway Bridges, as per scheme	800	٥	0
Causeway Bridges, as per scheme  'To ditto at Bariing's Eau and Stainfield Beck, and repairing the banks thereof to the dimen-			
flores mentioned in the scheme	500	0	0
To scouring out and imbanking Duns Dike (or the Carr Dike) as directed in the scheme	400	0	0:
To ditto of Noston Dike	275	0	0
To ditto of Washingberough Beck	60	0	0
To ditto of Tupham Dike, Bardney or Tilehouse Beck, Southery Eau, and Stixwoold Beck -	360	0	0
To unforeseen and incidental contingencies, surpervising, and officers to attend this work -	3000	0	0
Total for the works of general drainage	37849	9	5

## An ESTIMATE of fuch works as concern navigation only, viz.

	L.	Zi.	4.
To making and erecting the fide lock or penn fluice, as proposed in the scheme -	1200	0	0
To building 3 locks with proper walter and flood gates, as per scheme, between Chappel Hill			
and Lincoln	2000	0	0
To three watch-houses, and purchasing the ground	150	0	0
To erecting the proposed lock in Lincoln above Sincil Dike, as per scheme -	400	0	0
There will also be a necessity to deepen the bed of the mother river for the purposes of naviga-			-
tion, over and above what is required for draining, upon an average 13 inches, from Chap-			
pel Hill to Lincoln, which is 261 miles, and will cost about 80l. per mile, and comes to	2120	O	0
And for deepening the passage from the lock above Sincil Dike, through the high bridge, into			
Brayford Meer	200	0	0
To materials of barrows and planks, engines, gang ladders, tressells, &c. for this work -	500	0	0
To unforeseen contingencies and supervising the works =	800	0	0
I o municipal continue and and a series and			
Total for navigation	7370	0	a

F 2

John Grundy.

Langley Edwards.

J. Smeaton.

Sleaford, November 23, 1761.

The

## RIVER CHELMER NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of making the river Chelmer navigable from Malden to Chelmfford, in the county of Effex, from a view thereof taken the 28th and 29th of May, 1762; from whence it appears as follows:

Ift. THAT the fiver above Chelmsford bridge, which runs alongfide the town for about a furlong, is sufficiently deep and capacious for navigation, and so continues below the said bridge, till within about half a surlong of Monseholm Mill, where it seems too shallow. This tract of the river appears convenient for wharfs and landing-places; but in case it should be thought proper to carry the navigation above bridge, one of the arches must be taken down and rebuilt, none of them being of sufficient capacity for the crast to pass. There is also ample convenience for making wharfs, either by pursuing the Chelmer, or by cuts through the level meadows on the north-east side of the town.

2d. Mouseholm Mill may be passed by a cut and a lock on either side, but I apprehend with most convenience on the north side, the cut to fall into the river about half a furlong below the mill, where the river makes a remarkable elbow to the north. This will avoid the shoals below the mill; the water from the waste gates of the Chelmer near the town to fall into this new cut below the lock, and be conveyed thereby to the point already remarked.

3d. From the point above remarked, the river continues good till about half a furlong above Harrington's Mill, where there are further obstructions, which continue below that mill very near to Sanford Mill, and below Sanford Mill the river is remarkably narrow, winding, and obstructed with weeds and beds of fand and gravel for above a mile, and grows very little better till opposite Captain Honeden's house; after that it is still winding, and much obstructed with weeds, &c. till a quarter of a mile above Boreham Mill; but below the paper mill the river is again shallow, narrow, and obstructed, so as to be in no respect fit for navigation, till a little below Langford Church (which stands within 15 yards of the river); from hence the river is spacious and good down to How Mill. The river at How Mill, and from half a surlong above, verges so close to the high land, that no cut is practicable there on the south side of the river; but on the north side there is an extent of slat meadows.

4th. Now considering the great difficulties and obstructions that occur in the river, between Harrington's Mill and Langford Church, a space near upon 7 miles, and that no part worthy of consideration appears at present in a navigable state, except the space aforesaid, about three quarters of a mile between Boreham Bridges and Paper-mill; and considering that the extra charges in getting into and out of the river, in order to occupy this space, would nearly be equivalent to the expence of continuing a cut by the same, I am therefore of opinion, that the most cheap, as well as effectual method of making a navigation, would be to desert the river at an elbow about half a surlong above Harrington's Mill, veering away towards the south-east till it meets the high ground, and then pursuing the skirts of the rising ground, that is, as much as possible the consines between the upland and the meadows, which is in general land of the least value. A cut may be continued with very little interruption on the south side of the river from the point aforesaid, just above Harrington's Mill, to another point a little below Langford Church, making locks at proper places, so as to suit the declivity of the ground.

5th. The course of the river below How Mill becomes again narrow, shallow, winding, and obstructed with weeds for a space of 2 miles, and is not sufficient for navigation till about half a mile above Bealy Mill, and from thence it holds good to Bealy Mill.

or no flux here. The distance from thence to Malden, by the course of the river, is somewhat less than a mile; and the water runs upon a gentle declivity at low water, from those mills to Malden Bridge. The common spring tides show 8 seet, or upwards, at Malden Bridge, and the neap tides about 3 seet; but the neap tides sometimes sall so short, even here, as not to rise above 1 foot. These observations, concerning the tides, were taken partly from my own observations of the tide marks, and partly from the best information I could procure upon the place.

7th. Confidering the natural course of the river from How Mill to Maiden Bridge, as aforesaid, I am of opinion, that the cheapest way to make the most perfect navigation the circumstance will admit of, is to take a cut out of How Mill pond, with a lock thereupon, leaving How Mill to the south, and either keeping wholly to the north of the river, or otherwise intersecting the river twice within three quarters of a mile below How river, or otherwise intersecting the river twice within three quarters of a mile below How Mill, to pass by Bealy Mill, without coming into its pond at all, leaving that mill on the south.

fouth, and keeping down the meadows to drop into the river a little above Malden Bridge, on the north fide of the river.

'Tis true that the cut might ultimately drop into the river just below Bealy Mill, which would save about three quarters of a mile of cut; but as there is, according to the above information, at a medium, near 3 feet more tide at Malden Bridge than at Bealy Mill, the difference would be, that in one case a communication between Chelmsford and Melden would seldom be interrupted, and in the other case never open but at spring tides.

Upon the whole, I am of opinion, that though there is a possibility to make the river Chelmer navigable by its natural course, yet there is so small a proportion thereof that is at present adapted to navigation, that it will prove the least expence, and by far the most eligible method, to perform the same chiesly by canals, in the manner above specified, which canals being supplied with sufficient bridges for the public roads, carriage and other bridges for communication between private properties, under-ground tunnels and passages for brooks and water-courses, and back drains for carrying off any soakage that may happen where the water is confined by banks above foil; I fay, things being thus provided for, the private properties of land will be no otherwise affected, than by so much diminution as shall be necessary for the works themselves. And having made observations on the quantity of water current in the Chelmer at the time of this view, I am of opinion, that one 60th part thereof will be sufficient for passing one vessel per day, and consequently that the mills will not be sensibly affected by loss of water, at the same time they are most of them capable of being improved to near double their present produce. Lastly, having considered the above particulars, and made an estimate of the expence, so far as I can judge without a more particular and accurate furvey of the whole, supposing the length not to exceed 13 miles of new canal, the whole fall not exceeding 67 feet, and the value of the land not exceeding 601. per acre, 3 feet navigable water, and the whole performed so as not to require above 11. per Cent. per Ann. of the first expence to keep the same in repair for ever, may be done for 166971.

Austhorpe, 21 June, 1762.

J. SMEATON.

#### POTTERICK CARR.

The REPORT of JOHN SMEATON, Engineer, concerning the drainage of Potterick Carr, near Doncaster, in the county of York; from a view and levels taken in July, 1762.

POTTERICK CARR is a fenny piece of ground, containing, as appears by an old furvey of Saxton's, about 2300 acres: in its present state, no brook or spring of any account discharges itself thereupon, so that it is affected only by the down-sall waters which fall immediately thereon, and from the higher grounds which border upon the same. These down-sall waters, however, on account of the natural status of its surface, the impersection of its present drains, and the want of a sufficient out-sall to discharge them, generally overslow the whole, or greatest part thereof, during the winter season; which waters are partly discharged by the drains, and partly evaporated by the sun, so as in dry summers to be tolerably dry, as was the case when the present view thereof was taken.

This carr is bounded on the S. E. by the river Torne, which runs considerably above the surface of the carr; but is banked off, so as seldom to overflow the same; the whole drainage of the carr is therefore performed by a separate drain, called Stecking Dyke, which salls into the Torne, near Rosington Bridge, about half a mile below the lowest point of the carr.

On the opposite side of the river Torne, extending the whole space that river borders upon Potterick Carr, and somewhat higher, is Holmes Carr, consisting of some hundred acres, which are also banked off from the Torne, so as to be seldom overslowed thereby. The surface of this carr, for the greatest part, lays also below the surface of the contiguous river, yet somewhat higher than Potterick. This carr is however subject to the same inconveniencies as Potterick Carr; for in this are scarcely any drains at all, so that the down-sall water is obliged to find its way over the surface, by a natural declivity, into the river Torne.

Part of the fouth fide of Potterick Carr is bounded by Crookbill bank and drain, which prevents the spring and down-fall waters from Loversal from entering the carr, and which are carried by the said drain into the Torne, at a place called Crookbill Nook.

On the fouth fide of Crookbill bank and drain, and bordering on the river Torne, is a large tract of low land, called Wadworth Carr, the furface whereof lays confiderably higher

higher than Petterick Carr; but as the out-fall of its drainage is into the Torne at Crook-bill Nook, and the furface of the Torne there being some seet higher than at Resington Bridge, the drainage of Wadworth Carr is in much the same condition as that of Potterick Carr; and this is said to be the case with a large tract of country bordering upon Wadworth Carr, and extending upwards as far as Tickhill. I therefore propose to consider the drainage of Potterick Carr in a two-fold light: first, as it is, or may be, connected with the drainage and improvement of this large tract of country; and secondly, as to what concerns Potterick Carr alone.

On this account, I viewed the whole river Terne, from Resington Bridge, to the out-sall of its waters at Austhorpe sluice, which is a space that, sollowing the banks thereof, cannot be less than 22 miles; I also pursued the drains leading to Austhorpe sluice, quite across, by way of the old Dunn, to Thorn sluice, and from thence into the present river Dunn. I also carried a level from the river Dunn, at the crimpsal above Dencaster, cross the little moor and the high ground, whereon is the road leading from Dencaster to Loversal, at Balby out-gang gate; thence cross Posterick Carr, by way of the old Eau (a natural lake therein), down to its lowest point, called Toad Holes; thence, by way of Stecking Dyke, to Rosington Bridge, and down to the beginning of the participants drain, about 5 miles below Rosington Bridge, and about 300 yards above Gatewood Bridge. I likewise carried a level from the surface of the Terne, at Crockbill Nook, to Resington Bridge, comparing the same with the surface of Potterick, Wadwerth, and Holmes Carrs; and, lastly, a level from the surface of the water of the old Eau, to the top of the lowest grounds of the bridge on Cantley Common, near Doncaster horse course. From which views and levels I would lay down the following facts and observations.

# LEVELS from the Dunn at the Crimpfal above Doncaster, to the Participants Drain, near Gatewood Bridge.

1st. Mean surface of the Crimpsal above the water of the Dunn, opposite Neavion, 27 July,	F.	I.
1762,	8	0
2d. Mean surface of the grounds lying between the Crimpfal and the Little Moor, above the said		
point of the Dunn's furface,	17	0
3d. Mean surface of the Little Moor, above the Dunn,	14	0
4th. The causeway in the road from Doncaster to Loversai, opposite Balby Out-gang gate, above		
the furface of the Dunn,	39	74
5th. The mean surface of Potterick Carr, about 100 yards within the border thereof, near the	:	
Out-gang gate, above the said surface of the Dunn,	5	21
6th. The lowest part of the Carr's surface, near the Division Dyke, on the west side of the dyke	,	
and on Loverfal fide of the Carr, is nearly level with the surface at the former station, and		
therefore above the Dunn,	- 5	23
	7th.	The

th. The furface of the water in the old Eau, which may be esteemed the fink of the Car?	4.	I.
above the Dunn's surface,	4	4
th. The furface of the Carr at the Toad Holes, near the old engine, above the furface of the		
old Eau,	1	2
th. The surface of the river Torne, just below Resington Bridge, below the old Eau, including		
a full at the bridge made by the carriages driving through the water, amounting to 2\frac{1}{2} inches, oth. The furface of the river Torne, at the bottom of the strait cut or river, extending about	0	105
a furlong below Rosington Bridge, below the surface of the old Eau.	1	0
11th. The surface of the river Torne, opposite a birch tree at the side of the meadow on the	•	9
fouth fide of the river, about 5 furlongs below Rosington Bridge, below the old Eau,	4	0
12th. The surface of the river Torne, just above the houses at Oakly Dam, above the old Eau,	4	81
13th. The surface of the river Torne at the foot bridge, about 100 yards below the road at		
Oakly Dam, below the furface of the old Eau	6	0
14th. The surface of the river Torne, at the entry of the Participants Drain, about 5 miles be-		
low Rosington Bridge, and about 300 yards above Gatewood Bridge, below the surface of the		
water in the old Eau,	9	65
Confequently,		
15th. The surface of the river Torne, at the birch tree below Rosington Bridge, is higher than		
the surface of the Dunn, at the Crimpfal, by	0	4
16th. And the surface of the Torne, at the entry of the Participants Drain, is lower than the	5	2 1
furface of the Dunn at the Crimpfal, by		
TOTALL Com Caichbill Nort to Refugger Reider.		
LEVELS from Criekhill Nook to Rosington Bridge.		
17th. The general surface of Wadavorth Carr, near Crookbill Nook, above the surface of the		
C. LL:// Alask as was taken 20th July, 1702,	0	9
18th. The mean surface of one of the lowest slades near Crookbill Nook, above the surface of		4 I
	0	1 1 2.
19th. The mean surface of the lowest part of Holme's Carr, opposite Crookbill Nook, below	0	91
and the state of t		7.
the furface of the Torne there,  20th. The general furface of Potterick Carr, in the meadows adjoining to Crookbill Nook, be-	1	27
low the surface of the Torne there,  21st. The height of the bank of the Torne, above water, at some of the lowest places on the		
Holme's Carr fide, near Crookbill Nook, and which the Torne is said very rarely to over-top,	0	11
and the state of t	0	111
22d. Ditto, on the side of Potterick Carr, on the side of Potterick Carr, called the Total Holes, below 23d. Surface of the Torne, at the lowest part of Potterick Carr, called the Total Holes, below		0
		\$
the surface of the Torne, at Crockbill Nook,  24th. Surface of the Torne just below Resington Bridge, including the fall of 21 inches there,	7	5
below the surface of the Torne, at Crookbill Nook,	3	
Consequently,		
25th. From the general surface of the lowest part of Holme's Carr, near Creekotti Nook, to the	2	$7\frac{1}{2}$
25th. From the general surface of the lowest part of Holme's Carr, near Creekbill Nook, to the surface of the Torne, at Rosington Bridge, there is a fall of	z L	7 <sup>‡</sup> EVEL

## LEVEL from the old Eau to Cantley Common.

6th. July 30th, 1762, fo	ound the ri	le from the	ne furface of t	he water	of the old	Eau, to the	top	F.	I.
of Cantley Common, in	the lowest	part of	the ridge betw	een the	division dyke	e and the 1	ncto-		
fures next Doncafter,		-	-	-	-	40		15	O <sup>3</sup>

#### OBSERVATIONS.

from low water mark in the river Dunn, near Thorne Sluice, to low water mark in the Trent, at Authorpe Sluice; and from the above levels, Articles 7th and 14th, it appears, that the surface of the Thorne, at the beginning of the Participants Drain, is lower than the Dunn at the Crimpsal, by 5 seet 2't inches; but as this will scarcely balance the difference at Doncaster Lock, it follows, that the Torne, from the entry of the Participants Drain, would have a fall into the river Dunn, at or near Thorne Sluice, at least equal to the sum of the falls of the sour locks upon the river Dunn below Doncaster, and therefore has at least an equal one into the drain leading to Authorpe Sluice, which may probably amount in the whole to 12 or 14 feet, besides the 5 seet 2½ inches above mentioned.

from Potterick Carr to the Dunn, without traversing the ridge of hills extending from Loversal to Hatsield, without going below Hatsield; and since the same point can be attained by following the valley of the Torne, I therefore look upon the cutting through the high ground, at Cantley Common, in order to come at the same point, as quite out of the question; and to traverse the aforesaid ridge of hills, after passing through those high grounds, will be less eligible than traversing the same at the out-gang gate, and finding the shortest way to the Dunn.

29th. It is generally looked upon, that a capacity of reducing the surface of the water in the drains 2 feet under the general surface of the lowest lands to be drained thereby, to be effectual for draining purposes, and therefore whatever means are capable of producing this effect, will answer the end as well as if they were capable of making a greater reduction, because the surface of the water being too much reduced, with respect to the surface of sen lands, is found to hurt the sertility thereof.

#### GENERAL SCHEME.

NOW, with respect to the general drainage of the country, I take it for granted, that what will drain the lowest slades of Wadworth Carr, near Crookbill Nook, will, by proper leading drains, do for all the lands that lay further up the country; but as there appears to be from the levels, Articles 17th and 20th, a fall of almost 2 feet from Wadworth Carr into Potterick Carr, which would be sufficient for the drainage of the former, yet, was the down-fall waters of Wadworth Carr and country above let down, to as to communicate with the drains of Potterick Carr, the former would over-ride, and thereby prevent the drainage of the latter, unless both were carried separately to a point where a fufficient declivity might be obtained, so as to carry off both without affecting each other. This purpose may be obtained by cutting new drains separate from the river Torne, so as to deliver their water into the Torne, at the birch tree, below Rosington Bridge, before mentioned (Art. 11.) and still more effectually was the river scoured out, and a bridge built at Oakley Dam, where, from Art. 12 and 13, it appears, that 151 inches of level might be obtained in little more than 100 yards, the loss of which is a great detriment to the grounds lying on both fides of the river, between the said birch tree and Oakley Dam, during which space the river being deeper than in most other places, would reduce its surface a great part of that quantity lower than at present.

To this scheme will probably be objected, that the down-fall water of a large tract of country being brought down into the Torne at the birch tree, by more direct passages than heretofore, will be the means of overflowing the meadows below the faid point, and also raise the waters in the out-fall drain to a greater height than they would otherwife do. And it must be acknowledged, that something of this would take place, though in so small a degree, as scarcely to be sensible at so great a distance from the out-fall; for it must be allowed, that in wet seasons the same quantity of water must be discharged, the only difference is in the time. It must also be allowed, that the water which comes down the drains to the birch tree, must otherwise have come down the Torne to the same point, and therefore the water of the Torne will be eased by that quantity. The time therefore can only be affected by that part which comes down to the drains quicker than it would have done by the Torne; but then in consequence of this quickness being nearer its out-fall, and coming by a more direct road, it will generally happen that the bulk of the down-fall coming by the drains will be gone off, before the bulk of the land waters that come from other places at a great distance by G 2

the meandring course of the Torne are arrived; and consequently, in such cases, the rapidity of the waters coming down will, upon the whole, be rather abated than increased.

But if this reasoning, however true and explicit, should not prove satisfactory to those who are to get nothing by perceiving the truth thereof, I see no way of steering clear of the objection, but by bringing a new drain from the river Dunn, entirely independent of the river Torne; and I do not find any better way of doing this, than by beginning at some proper point upon the river Dunn, below Stainford lock, and above Thorne sluice, from thence traversing the level moors, and leaving Gatewood to the north, to approach near the Torne at Gatewood Bridge, and leaving this bridge, as well as the whole river Torne, on the south, to follow the low meadows quite away to Potterick Carr, and through the same up Wadworth Carr, &c.

In this case, it would be necessary to erect a small sluice at the out-fall of this drain into the Dunn. This method would effectually drain, not only all the country above Rosington Bridge, but be of great service to the lands through which it passed below, and might be executed at a moderate expence; for though the distance is considerable, yet there is so great a sufficiency of level, as appears by Art. 27, that a small drain would answer the end. This drain would be somewhat shortened, and the out-fall sluice avoided, in case the proposed scheme for making a navigable communication between the Dunn near Thorne Sluice, and the Trent near Authorpe Sluice, should take place; in which case, the two schemes would be of mutual assistance to each other. Yet as the execution of this scheme of drainage, in either method, however practicable in nature and art, would necessarily pass through and sever many properties, how far it may be practicable respecting mens interests and opinions, I cannot take upon me to say.

## SCHEME for POTTERICK CARR.

I come now to consider what may be done towards the drainage of Potterick Carr, independent of the rest of the country, by such methods as lay within a narrower compass, and as it were within the districts of the corporation of Doncaster, and proprietor of Loversal. And here two methods offer themselves; one by a subteraneous passage from Potterick Carr to the river Dunn, by way of the Crimpsal; the other by way of Stecking Dyke, which appears to be the antient out-sall drain for Potterick Carr into the Torne, at or near Rosington Bridge.

appears, Art. 7, that when the levels were taken, there was a fall of 4 feet 4 inches from the furface of the old Eau to the furface of the river Dunn, the distance being about 2 miles. It appears also, Articles 5, 6, 7, and 8, that the surface of the old Eau at that time was about 10 inches below the general surface of the Carr; therefore a capacity of running off the surface of the old Eau 14 inches lower than at present, would, with proper internal drains, compleat the drainage of this Carr, and still there would remain 3 feet 2 inches sall from the water of the old Eau to the surface of the Dunn; but as the verge of the Carr, near Balby out-gang gate, is about a mile nearer to the Dunn; to which all the water of the Carr would be brought, in open drains, with very little loss of level, there would be 3 feet descent for the subterraneous passage, which from this point would not, in the nearest direction, be above a mile, which is so large an allowance of descent, that supposing clean bottom carried upon dead level from the surface of the Dunn, a drain of 3 feet wide would sufficiently discharge the water.

The disadvantages attending this scheme would be, that whenever the surface of the Dunn should, in rainy seasons, be kept higher than 3 seet above its common pitch, which I suppose it sometimes is for weeks together, that then there could be no drainage at all; but, on the contrary, without the help of a subterraneous sluice, the water of the Dunn would run into the Carr.

This inconvenience would, in great measure, be obviated by carrying the drain so low as to fall into the river Dunn, between the water-engine and the bridge at Doncaster; for this would gain an addition of 5 or 6 seet of level. And though, in the height of great sloods, I suppose there is not a great deal of difference of the Dunn's surface above and below the engine-dam, yet I suppose that the water rarely continues there for any length of time together, so as to be 3 seet higher in the engine-tail than the ordinary surface of the Dunn, at the Crimpsal, opposite Newton. So that the drainage being stopped but for a little time together, would be sufficiently performed by intervals: but then, as this will create about three quarters of a mile addition of drain, and thereby add to the tediousness and expence of an otherwise tedious and expensive job, it will still remain question, how far this method of drainage may be eligible, especially when 'tis considered, that, should a running sand be met with in this passage, it might prove an insurred thereupon.

2d. With

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But if this reasoning, however true and explicit, should not prove satisfactory to those who are to get nothing by perceiving the truth thereof, I see no way of steering clear of the objection, but by bringing a new drain from the river Dunn, entirely independent of the river Torne; and I do not find any better way of doing this, than by beginning at some proper point upon the river Dunn, below Stainford lock, and above Thorne sluice, from thence traversing the level moors, and leaving Gatewood to the north, to approach near the Torne at Gatewood Bridge, and leaving this bridge, as well as the whole river Torne, on the south, to follow the low meadows quite away to Potterick Carr, and through the same up Wadworth Carr, &c.

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1st. With

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2d. With

2d. With respect to a drainage into the Torne, if Stecking Dyke was carried down on the north side of the river, and dropt into the Torne, at the birch tree, below Rosington Bridge, this scheme would be undeniably the best of any; for to this place, from the old Eau, there is near upon the same fall as into the Dunn, at the Crimpsal, opposite Newton, with an opportunity of making a drain of any given capacity that may be required; and as it appears, from Art. 21 and 22, that the waters of the Torne don't rise in time of floods above a foot perpendicular, the flood water of the Torne can never over-ride those of the drain: and whatever force may be supposed to remain in the objection to the delivering the down-fall water of the whole country into the Torne at this point, it will entirely vanish when applied to Potterick Carr alone; for being of so much less extent, and nearer to its out-fall, and having so good a declivity, its water will be certainly discharged before those from the different parts of the country are come down; and in long-continued rains it is plain that when the Carr is once overflowed to a certain height (as is the case at the close of winter, when surface waters are most annoying) that the present discharge of water from the Carr, at those times, will be just equivalent to its discharge of water in the same time when in a state of drainage.

But I will now suppose the worst, and take it for granted that nothing can be done but by such lawful means as may be put in practice within the grounds of Doncaster and Loverfal.

It appears by the levels, Art. 9 and 10, that from the surface of the old Eau to the lower side of Rosington Bridge is a fall of 10 1 inches, and from thence to the lowest part of the straight cut, extending about a furlong below the bridge, is 10 1 inches more, in the whole I foot 9 inches; but as a reduction of the surface of the old Eau of 14 inches below its then state has been shewn sufficient for drainage, there will still remain 7 inches fall from the old Eau to the point last mentioned, which is amply sufficient, as the distance does not exceed a mile and half.

Now the straight cut aforesaid, below Rosington Bridge, (which passes through the bounds of the corporation of Doncaster, or Mr. DIXON, of Loversal,) plainly appears to have been made with a view to the drainage of Potterick Carr: for by cutting off the loops of the old river, and making a more free passage for the Torne, the surface of the water would naturally be reduced at the tail of Stecking Dyke, and consequently afford a better fall from the Carr; and even by this construction, had the whole been done in a proper method, and with proper dimensions, a drainage might have been accomplished, and with good management preserved to this day: but at present I would rather advise to let

the Torne continue its present course, and to cut a new drain on the north side thereof, through the said lands, from the lowest point of the said straight cut, up to Stecking Dyke; and either by scouring out and enlarging. Steeking Dyke, or by cutting a new drain in lieu thereof, this, with proper internal drains within the Carr, will reduce the water 2 feet 7 inches within the general furface of the lowest lands in dry seasons, unless held up to a greater height for the use of cattle.

It appears from Art. 21 and 22, that the greatest rise of the Torne in time of floods at Crookhill Nook does not exceed 1 foot perpendicular; but there is reason to suppose it may be somewhat more at the point before mentioned, possibly 15 inches, and therefore it will be necessary to place a fluice or doors at the tail of the drain to shut against the water of the Torne at such times, and prevent their reflowing into the Carr; yet, if the drains are made of sufficient depth and capacity to run off the waters of the Carr to the dead level of 2 feet 7 inches below foil, those drains will be sufficient to hold water, fo as to drain by intervals without overflowing the furface of the Carr.

It is possible the same objection may still be urged against this scheme as against the former, of going down to the birch tree, viz. that of bringing down the waters more fuddenly upon the lands below; but for this, in the present case, there is most evidently not the least foundation; for since it will be necessary to maintain a pair of doors to shut against the Torne in time of floods, it is plain the drainage water can make no addition while its doors are shut; and as they must escape when the bulk of the stoods in the Torne are spent, it must contribute to the carrying off the whole more equally than at present. And fince this scheme can be executed within the grounds of the parties concerned, and cannot possibly, even in appearance, prejudice those of any other, I apprehend there can be no doubt of the legality thereof; and as this scheme can be executed at much less expence than any other, for my own part, I think it merits trial.

I hope what has been said will be sufficient to let the proprietors of Potterick Carr see clearly the nature of this business, and to determine them in the choice of a method: when that is done, I shall be ready to make what further observations may be necessary, in order to lay down the particular plan and dimensions, and form an estimate thereupon.

With respect to Holmes Carr, it will readily occur, from what has been said, that there cannot be the least difficulty; for fince there is 2 feet  $7\frac{1}{2}$  inches fall from the lowest parts opposite Crookbill Nook to Rosington Bridge, that nothing more is necessary than to put Austhorpe, September, 1762.

J. SMEATON.

ESTIMATE for draining Potterick Carr, Holmes Carr, and Wadjworth Carr, by a passage from Potterick Carr, by Balby Out-gang gate and Spansdyke, to the river Dunn, below the engine at Doncaster; the tail of the drain to be laid 8 feet below the mean surface of the Carr, and to rise 1 foot to the Out-gang gate.

To digging out the tail-drain for an arch, length 5 chains, in order to get round the	
To digging out the tail-drain for an arch, length 5 changes, mean depth 10 feet bottom, engine into Mr. Copley's meadow, adjoining to Crimpfal; mean depth 10 feet bottom,	£. s. d.
engine into Mr. Copley's meadow, adjoining to Crimpus, and to batter half a foot in a foot a perpendicular, containing 1760 cube	
width 6 feet, and to batter than a root in	25 13 4
yards, at 3½ d. per yard,	
yards, at 3½ d. per yard,  To walling the fides 4½ feet high, which if done with Extrop stone, or brick  To walling the fides 4½ feet high, which if done with Extrop stone, or brick  L. s. d.	
length wall, may be done for 143. Per 1000, and - 6 12 0	
be 9 rood 3 yards,	
The floor being set with Extrop stone, 9 inches deep without mortar, if done  The floor being set with Extrop stone, 9 inches deep without mortar, if done  2 6 3	
and anch chain contains at the contains	
the Call builde at F 1991 113411 10 40 to	
To arching the same with orick, at 3 seet spans of the same with orick, at 3 seet spans of the same with orick, at 3 seet spans or the same with orick spans or the same with original spans or the same with orick spans or the same with original sp	
thick, 7 roods 6 yards	
•	
Value of 1 chain arching, 14 8 3	
Value of 1 chain archings	72 10 0
Which in round numbers we will call,	12
To 5 chains of arching, at 141. 101. per chain,	3 13 4
To 5 chains of arching, at 147. 103. per chain,  To ramming behind the walls, fitting-in and righting-up earth, at 15. per yard,  To temporary damages, at 1 d. per yard, upon the furface opened, containing 660 yards,  To temporary damages, at 1 d. per yard, upon the furface opened, containing 660 yards,  To temporary damages, at 1 d. per yard, upon the furface opened, containing 660 yards,	2 15 0
To temporary damages, at 1 d. per yard, upon the infrace openas, and hanging a To extra work, fecuring the apron, making a front wall next the river, and hanging a	
To extra work, fecuring the apron, making a front want next into the Carr in time	
To extra work, fecuring the apron, making a front want next the Carr in time fluice-door to prevent the water of the river Dunn from reverting into the Carr in time	20 0 0
of floods,	
Carried over &	124 11 8
	-

[ 49 ]			
	L.	s. d	
Brought over	124	u t	l .
From the aforesaid drain for 5 chains, through Mr. Copley's close, and from thence 24 chains			
through the Crimpfal, total length 29 chains, may be an open drain, which at 9 feet			
mean depth, 6 feet bottom, and 4 feet batter per yard perpendicular, turns out 11494			
vards, at 3 d	143 1	1	
The mean width of the cut at top will be 30 feet, which in 29 chains produces 6386 yards,			
equal to 1 acre, 1 rood, 11 perches, and each bank will nearly occupy the same space,			
but this is supposed to be left of half value, so that, for the two banks we reckon t acre,			
1 rood, 11 perches, and in the whole 2 acres, 1 roods, and 22 perches, which if valued			
10 60 l. per acre, comes to	158	5	0
From Crimpsal, up Spansyke Closes, 26,26 chains, mean depth 12 feet, with 6 feet bottom,			
and 4 to 3 slopes, will turn out 16995 yards, at 3d.	211	18	101
The mean width at top will be 38 feet, which at 26,26 chains long, makes 7315 yards,			-
The mean width at top will be 38 feet, which at 20,20 chains long, makes 7,305 and			
equal to I acre 2 roods a perches, which doubled for the cover makes 3 acres and	155	0	0
4 perches, which if valued at 50%.	30		0
A bridge across at the Extrop Road,	30		
From the top of Spansyke Closes to the entry upon of the little moor, is 184 chains, the mean			
depth 16 feet. The digging out a 6 feet bottom, with half a foot batter, in a foot		7.4	Q
high, will turn out 10664 cube yards, which m 4 d. comes to	177	14	-
To arching 18,5 chains, at 14/. 10s.	268	5	
To ramming, filling, and righting the ground, at \(\frac{1}{2}\) d. per cubic yard,	22	4	*
To temporary damages, at 1 d. per yard superficial of the ground opened, 3138, comes w	13	ı	6
From the entry of the little moor across the same to the bale of the hill, about one chain			
within the Green-Lane, is 23 chains, mean depth 17 feet; the digging out a 0 feet Dot-			
tom at 1/2 a foot batter, in 1 foot rife, will turn out 13859 yards, which at 4d. 2 yard			
comes to	230	19	
To 23 chains of arching, at 141, 101.	333	5	0
em cilia in andre unede at i d.	28	17	5 1
From the base of the hill, one chain upon the same being at medium 20 seet deep, with			
bottom and flopes = before, containing 782 cube yards, at 5 d.	16	5	10
	14	10	O
To arching ditto as before,	1	12	7
To filling ditto, 782 cube yards, at 1 d.			
To open casting on the side of the hill next the Carr one chain, mean depth 12 feet, with a	. 15	0	•
6 feet bottom, and flopes m before,	27		
To open-casting, arching, and filling one chain more, mean depth 16 feet, -			
To open-casting, arching, and filling one chain, mean depth 20 feet, as on the other side	33	0	•
of the hill,		-	
and the state of the hill.	2005	2	7
as flore through the Bill, Willell cannot be			
- A S A S A S A S A S A S A S A S A S A			
it turns out any kind of matter that will hand undepended; but as it may be attended	1		
with some extra trouble, if we allow 21, 101, per yard, then 286 yards at 21, 101	- 71	5	•
come to			
	£. 272		
Vol. I.			

( 50 )	_		,
Brought over	£	T+	d.
	2/20	2	7
To extra work in fixing a drawgate at the entry of the subterraneous passage, in order			
to take off the water, to repair or inspect any thing within, and which will also serve	20	^	_
for holding in water for the cattle in dry seasons,	20		Q
	2740	19	7
Estimated expence of the out-fail drains	2/40	-	
a transfer			
N. B. The whole length is 119 chains, or 17 mile wanting one chain.			
Mother drains, barrier bank, &c. within the Carrs.			
To digging a mother drain from the entry of the fubterraneous passage to the old East, be-			
To digging a mother drain from the entry of the described and at a medium 6 feet ing in length 12 mile, to be 21 feet top, 9 feet bottom, and at a medium 6 feet			
ing in length 14 mile, to be 21 teet top, y less to the	256	13	4
deep, containing 30800 cube yards, at z d.  To continuing the faid drain from the old Eau to Crookhill Nook, in order to receive the			
water by foxes, from Holmes Carr under the Torne, and from Wadworth Carr under Ca-			
therine Well Water, being in length 1 1 mile, to be 19 feet top, 9 feet bottom, and at 2			
medium 5 feet deep, containing 17111 yards, at 2d.	142	11	2
To the making a fox, about 2 yards wide and 1 yard high, for taking the water from			
Helmes Carr under the river Torne,	60		0
The about a stard fourte, from Wadworth Carr, with a thuttle for regulating the			
water, that it does not come down faster than the mother drains in Potterick Carr will			
	55	O	9
To cutting a back drain behind the bank of the Torne in Potterick Carr, and thereby			
threngthening the bank against the river, being in length about 1 & mile, to be 3 yards			
wood wideh and a varil deep, cutting and banking at 2d, per yard,	66	0	0
To ditto behind Crookbill Bank, mile (or so far as may be sound necessary) of the same			
dimensions	44	0	0
To coming a mother drain within Holmes Carr, parallel with the general course of the river,			
avoiding the loops, and therewith forming a bank against the same, leaving 20 seet sores			
land in the nearest places; the length supposed 2 in miles, (more or less as may be near			
cessary) to be 5 yards top, 2 yards bottom, and at a medium 4 1/2 feet deep, containing			
varde = 2 d	192	10	O
To cutting a mother drain, in like manner, in Wadworth Carr, dispoling the earth bank			
fathion as before-mentioned. The drain to be 4 + yards top, 1 2 bottom, and at a			
medium to $1\frac{1}{2}$ deep, supposing the length $1\frac{7}{2}$ miles (more or less, as may be necessary)			_
will contain 11880 yards, at 2 d.	99	0	0
To Grangthaning Catherine Well Water Bank against Wadavorth Carr by a back drain, 3		_	0
wards wide and I ward deep, supposing the same I mile (more or less, as may be required)	44	0	
To harding on both fides the drain by the fide of the road over Waaworth Carr, which			
brings down the water of some springs, and also for making catch-water drains to con-			
duct the upland water into the river, supposing the whole to be 2 \frac{1}{2} miles, (more of lets,	110	0	0
as may be wanted) 3 yards wide and 1 deep,			
	1060	14	6

Estimated charge of the internal works

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#### GENERAL ACCOUNT.

				•				L.	2.	d.	
The out-falls drain,	•	**		-	4	~	- +	2740	2	7	
The internal works,	46	~	-		-	-		1069	14	6	
Contingent expences	upon the whole,	the	perforation of	the hili	excepted,	-		400		0	
								-			
						Total	· L.	4209	17	1	

N. B. The sum marked thus + was in the original 27321. 6s. od. and the total marked thus was 42021. as. 6d.

#### OBSERVATIONS.

1st. In case a red sand rock should be found in the hill, at the level of the drain that will stand of itself, it may be done for 11. 5s. a yard, but in case it should be a soft clay, or running sand, it may cost 10 l. a yard.

2d. In case of such a sand or clay, it will be adviseable to sink for a firmer matter below, in which case, the water may be carried under the hill in manner of an inverted fyphon.

3d. If a red fand rock should lay in a right line between the engine and Carr, as the distance is only 65 chains, it might be cut for about 18281.

4th. If such a rock should be found between the top of Spansyke Closes, in a right line to the Carr, the length being 33 chains, the whole expence of the out-fall drain will be done for 1751 l. But

5th. If this last space should be the same matter as supposed in the estimate for Outgang gate, the out-fall drain would be done this way for 26591. but the hazard greater.

6th. As much depends upon the quality of the matter, it would be adviseable to bring this affair to a certainty, by finking or boring.

7th. The charge of carrying the drain from the top of Spanfyke Closes across the little moor to the entrance of the hill, will be somewhat cheaper by an open drain than by arching; but as the cut and banks would occupy between 50 and 60 yards broad, would be less eligible to the land owners, and the drain more liable to obstruction, by matter tumbling from fuch very high banks. N. B. The

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N. B. The bottom for the arching parts is supposed to be dug no more than 6 seet wide, though the drain within the walls is purposed to be of 5 feet, because the foot of the slopes may be cut down perpendicular half a foot on I side, when the masons are ready to put in the walls.

Doncaster, March 23, 1764.

I. SMEATON.

To Mr. SHEPPARD, concerning Potterick Carr.

SIR,

IN answer to your request, my report is as follows:

That in the dry season in July 1762, I sound the waters of the old Eau in Potterick Carr nearly 10 inches below the mean surface of the land in the Carr, which in the points I tried it was nearly upon a level, which are specified in my report, and to which I refer; that from the surface of the water in the old Eau, to the surface of the river Torne just below Rosington Bridge, I found a fall of 101 inches, and from thence to the bottom of the straight cut, or river below Rosington Bridge, 101 inches more, making together 1 foot 9 inches below the surface of the old Eau, as it and the river then were; but it is to be remarked, that the surface of the water in the river just below Rosington Bridge was 13 inches below the first apparent joint of the arch on the south-east angle thereof, whereas when I viewed it on the 20th of May last, it was nearly 6 inches above the same.

I also find from my notes taken in 1762, that from the bottom of the straight river aforesaid, to the birch tree mentioned in my Report, I made 2 stations, amounting together to 2 feet 3 inches fall; the first below being  $11\frac{1}{4}$  inches, and the second  $15\frac{3}{4}$ inches; but how far the first station of 11 inches extended below the straight cut, I do not now remember, having no remark thereupon, the extent of the corporation's estate on the fouth side of the river not being at that time distinctly pointed out to me; but I have reason to believe that at least 6 inches of the 11 would fall within the corporation's estate, so that hence I infer, that from the surface of the old Eau, to the surface of the river Torne, at the bottom of the corporation's estate, as the old Eau and river then were, was at least 2 feet 3 inches, and consequently below the mean surface in the Carr 3 feet 1 Inch, and which I don't doubt but will appear the same, whenever the obstructions, which I apprehend to be fince formed in the river below Rosington Bridge, are removed, so as to suffer the surface of the water to subside to the same point upon the bridge, as it was even with in 1762; and consequently, that with the fall above mentioned, the Carr may be effectually drained, as 2 feet below the furface is generally esteemed by the most experienced engineers a compleat drainage.

For this purpose, I apprehend it will be convenient to cut a new passage for the river Torne from some proper place at or above Crookbill Nook, and skirting the high ground on Rosington side, as much a consistent with a short course to bring the same down to Rosington Bridge, and building a new bridge for the new river on the south side of the present bridge, to carry down the new cut through the corporation's estate on the south side of the present river, and to drop the same into the Torne at the lowest point of the faid estate. This new river being properly embanked, will defend the lower grounds of Potterick Carr from the floods of the Torne, and by proper drains and tunnels will drain Holmes Carr, and the higher grounds to the westward of the same, without interfering with that of Potterick Carr.

The dimensions of this new river ought to be at least 20 feet bottom, with proper batters, or slopes, of at least 1 to 1. The bottom at the tail of the new river to be at least 2 seet below the surface of the Torne there, as it was in July 1762, that is, 4 feet 6 inches nearly below the said joint in the arch, and to rise upon a plane regularly inclined, so as to be at least 4 seet below the surface of the adjacent carrs, where it joins the old river at or above Crookbill Nook.

For the drainage of Potterick Carr, I would recommend to cut a new drain between the proposed new river and the old one, beginning at the old river just above the tail of the new one, and joining the straight river as soon as possible, to widen and deepen the same in its present course, so as to pass under the present Rosington Bridge; and from thence keeping on the north fide of the old river above Rosington Bridge, to join Stecking Dyke, widening and deepening the same nearly according to its present course, to the place where the engine stood, from thence keeping a straight course, or as nearly so as the convenience of properties will allow, through the middle of the Carr to the north end thereof.

This drain I would recommend to be at least 18 feet wide at the bottom, with slopes of at least 1 to 1, and to be at least 5 seet 6 inches below the said joint in the arch, the

Carr

bottom to be carried upon a dead level, and of an equal width as far into the Carr, till it is opposite the old Eau, from thence to grow gradually narrower and shallower, so as to be 4 feet deep and 5 feet bottom at the head; this, with proper cross drains, will reduce the water in the Carr to very near the same level as the river at the out-sall of the drain. I would further advise that a sluice with doors, pointing toward the Torne, be erected at the tail of the drain, to prevent the water of the Torne in great rains from over-riding those of the Carr, and thereby reverting into the Carr, and also a stop-sluice with draw-doors upon the tail of the proposed new river, by shutting which, at proper times, the proposed drain will run at times, when it otherwise would not; a sluice-keeper being appointed to take care of the drawing and shutting the same, so as to prevent their running or penning improperly, on account of the lands above and below.

A catch-water drain round the skirt of the Carr will be of great use, in conveying the water from the uplands into the new river, without entering the Carr; but as the country is not very extensive which at present throws down water upon the Carr, this expedient need not be put in practice till experience shews it to be wanted.

The above reasoning principally depends upon two points, which I would recommend to the commissioners to satisfy themselves upon, viz. whether obstructions in the river below the corporation's estate can or cannot be removed, so as to run off the water to the same depth as I sound it in my survey in July 1762; and secondly, whether, in that state of the river, there is or is not the quantity of fall specified, or near upon.

I am, SIR,

Your most humble servant,

JOHN SMEATON.

P. S. The joint of the arch being a little inclined, I took my measure from the lowest fide next the water.

The REPORT of John Smeaton and John Grundy, Engineers, concerning the practicability of improving the Fossiyke navigation, and draining the land laying thereupon; from view and levels taken in August, 1762.

THE Fossayke is an artificial cut or canal, which joins the Trent and Witham together, by a navigable communication, extending from the Trent, near Torksey, to Brayford Meer, near the city of Lincoln, being in length near upon 11 miles. The river Witham, which has its origin near Post Witham, in Lincolnshire, after pursuing course of about 40 miles, falls into Brayford Meer, which being a natural reservoir of several acres in surface, and having an open communication with the Fossayke, as also with two other still more extensive lakes, or natural reservoirs, called Swan Pool and Cuckoo Pool, their surfaces being common, and nearly rest, will, consequently, be nearly upon the same level, and rise and fall together.

The end of the Fossayke next the Trent is thut by a lock, having gates pointing both ways, which, of confequence, equally prevent the waters of Fossayke from flowing out into the Trent, or the waters of the Trent from flowing into the Fossake, according as each surface happens to be lower or higher than the other. The waters of Brayford Meer, and consequently of the Fossayke, are prevented from running off below a certain height, by a shoal in the river Witham, between Brayford Meer and Lincoln High Bridge, called Brayford Head, or the Natural Stanch. There are also three other passages for the water of the Witham, before it falls into Brayford Meer, which are called Sincil Dyke, and the two Gowt Bridge Drains; the two latter join the former, and fall into the river Witham below the said shoal of Brayford Head, a little above Stamp End, which is the lowest point of the city of Lincoln; from hence the waters of the Witham make their way through the fens towards Boston; but as the highest part of the bottom of Sincil Dyke and Gowt Bridge Drains is several inches higher than the top of the shoal of Brayford Head, those ferve only as slaker drains, to ease off the passage of the water in time of sloods; but Brayford Head is considered as the gage, weir, stanch, or tumbling bay, by which the water of Brayford Meer is kept up to a certain height, and discharged when above the same.

Now there being a great quantity of low grounds, which have their drainage into Brayford Meer and into the Fossayke, and their communications, which cannot, in the present state of Brayford Meer, be effectually drained, for want of a sufficient stall from the

the lowest parts of their surface, it is therefore desirable to the proprietors of those lands that Brayford Head should be removed, or at least so far lowered, that the water of Brayford Meer, and consequently the Fossayke water, being so much sunk below its prepresent gage surface, as to afford a sufficient declivity from the surface of the lands thereinto.

On the other hand, the Fossike navigation being at present deficient in depth of water, it is equally desirable to the proprietors thereof that Brayford Head should be raised.

To reconcile those opposite interests, and give to each party what they desire, without injury to the other, is the point at present before us.

In the first place it is very obvious that, was Brayford Head lowered a certain number of inches, and the bottom of the Fossayke lowered as much, that the lands would be bettered, and the Fossayke navigation would be in the same state as now; and if beyond that the bottom of the Fossayke was lowered as many inches more as it is at present deficient, then the navigation would be bettered also, and both sides would get what they want.

In order to examine the merits of this proposition, we sounded the depths of the Fossayke, and examined the qualities of its bottom, measured the width, and took the height of the banks, in a variety of places, between one end and the other, and made what other observations we could, in order to inform ourselves with the circumstances that would be likely to occur in the execution of such a project: in consequence whereof, we found that (some sew places excepted) the bottom was either a rotten peat earth, or else a running sand; and from the efforts that have already been made from time to time, in order to clear the bottom, and by the wharfing up the sides with piles, plank, and stone, well as from the nature of the soil itself, it appears to us to be very difficult and expensive to preserve the present depth of water upon its present width; and though we are of opinion that the deepening thereof in the requisite degree to answer the purposes aforesaid, is in nature possible, yet, as it appears to us that this deepening cannot be effected without moving one of the banks, in order to widen the same, and give a proper foreland thereto, and that in very considerable degree for the greatest part of the length, it will, in consequence, not only turn out a very expensive project, which, by an estimate we have made thereof, amounts to upwards of 60001. but be the occasion of much loss of time and profit to the proprietors of the navigation while owners themselves as the following scheme of drainage would be; for it is most manifest, that no grounds which drain into Brayford Meer, Fossaye, or any of the pools or communications that lay upon the same level therewith, can receive any greater prejudice by the present height of water in the Fossaye than heretosore, unless it can be proved that Brayford Head is now higher than it was, for if it is not, the expence of such deepening must in a great measure fall upon the proprietors of lands, for whose sake principally it is done, it being no matter which concerns the proprietors of land, how deep the bottom of Fossaye is below the gage surface of its water, but only whether this gage surface is higher now than it was; if not, and the lessors and lessee of the Fossaye are disposed to be contented with its present depth, rather than be at the charge of deepening, the deepening, with all its consequences, will then become the business of the land owners only, except what it shall be reasonable for the Fossaye proprietors to contribute, for the advantage of a greater depth than at present, after all losses and damages that they shall sustain thereby are made good.

Whether Brayford Head is higher now than formerly, is not for us positively to determine; and though it is possible some accession of matter might have come to Brayford Head from various causes and accidents, yet as the shoal is not composed of sixt matter, it may notwithstanding have been upon the whole in a state of diminution, rather than increase, since the increase of traffick, by the passing of boats and carriages upon and over it.

Having viewed and taken the levels of various points of the surface of those lands which drain into Fossake, Brayford Meer, or their communications, we find those most subject to be drowned are as follows.

On the fouth of Fossake are Lincoln Holmes, Bootham low grounds, Skellingthorpe low grounds, and part of Saxelby pasture: on the north of the Fossake are part of the Lincoln Common, Burton Fen, South Carlton Fen, North Carlton Fen, and a small part of Brox-bolme, Haddow, and Saxelby low grounds, upon the Till.

The furface of the grounds abovementioned are at a variety of elevations above the level of Fossake water; yet the greatest part thereof were less than 3 feet, and we level of Fossake water; yet the greatest part thereof were less than 3 feet, and we sound no considerable quantity but what was at the time of this view 1 foot and upwards above the Fossake, (the greatest part being from 1 foot to 1 foot 6 inches) except the above the Fossake, (the greatest part being from 1 foot to 1 foot 6 inches) except the Hassake in Lincoln Holme, (being in a manner a bog) a small part of the low slade which Vol. I.

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extends from the Fossike to Bishop Bridge on Lincoln Common, and a small quantity in Saxelby pasture opposite to the Till, which were but little elevated above the Fossike surface. But the lowest ground of any consequence, is a slade extending from Cuckoo Pool to Saxelby pasture, which appears to have been the course of the Till before the Fossike was originally cut; this was from 5 inches to about a foot above the said Fossike surface. At the time when this view was taken, there was at a medium, as before mentioned, 4½ inches water upon Brayford Ilead; from the best information there is scarcely ever less than 3 inches, and in great winter floods, full 4 feet; so that it may be reasonably conjectured, and we have been so informed, that in the spring of the year, and at all other times until the said flood waters, which have expanded themselves over that large tract of low grounds above Lincoln, are exhausted, there can seldom be less than 10 inches water thereon.

The principal opening for the discharge of those waters of the IVitham, and from this tract of land under consideration, is through Lincoln High Bridge, which in the narrowest part is no more than 15½ feet; besides which are Sincil Dyke and the two Goat Bridge Drains aforesaid, which though greater in width when taken together, yet from laying considerably higher, and from those drains being very defective, are not capable of discharging more water than the High Bridge singly.

From hence it appears, that the low lands before mentioned, when once overflowed, their drains having an open communication with each other, must remain under water during the winter, and a great part of the spring season, and are without the compass of a compleat drainage in their present situation.

Imbanking and engines are a general method of drainage, which may be put in practice where nothing else can; but the certain expence, and uncertain effect thereof at critical times, have made all drainers preser the use of natural means, where those natural means can be had.

On examining the Fossayke, we find the general bottom to be about 2 feet 8 inches below the level of Brayford Head, in some sew places less; but as they are only short distances, they will easily be reduced to a proper depth by dredging, so that there is wanting to inches of depth in order to compleat the navigation to 3 feet 6 inches; for the addition that will be made by 3 or 4 inches of water constantly going over Brayford Head, will give a sufficiency of free water for navigating vessels drawing 3 feet 6 inches. In order therefore to give the Fossayke this necessary addition, and at the same time to

drain

drain the lands in question without detriment to any other, we propose a scheme sounded on the following facts.

- the furface of the water of Brayford Meer, when at its ordinary furnmer's height, is a rife of 14 inches; but from the surface of the river at Stamford to the same place, is a rife of 1 foot 7 inches and a half; and from the surface of the Brayford Meer, to the surface by Bailey's Sluice, is 2 feet  $5\frac{1}{5}$  inches.
- 2d. That from the surface of Brayford Meer, to the surface of the river Witham, at the upper mouth of Sincil Dyke, which runs under Bargate Bridge, is a rise of 1 soot 6 inches.
- 3d. From the surface of Brayford Meer, to the surface of the river Witham at Brace Bridge, is a rise of 3 seet 2 inches.
- 4th. From the natural stanch of Brayford Head, to the bottom of the river at Brace Bridge, forming a natural stanch, there is a rise of 2 feet 6 inches.
- 5th. That from Brayford Head, to the bottom of Sincil Dyke Drain, at its highest part, near Bargate Bridge, is a rise of 1 foot 7; inches; and from Brayford to the mean highest bottom of the Gowt Bridge Drains, is 1 foot 3; inches.
- N. B. At the time of this view, the Sincil Dyke and two Gowt Bridge Drains were all running about 3 inches over their highest points.
- 6th. We found, from our levels and observations, that all the low grounds adjoining upon the Till, are on so high a level above the surface of the Fossake, that they will have a drainage therein on the decline of floods, except about 40 acres, contained in a narrow screed by the old course of the Till side, from Haddow Bridge, about half a mile upwards, the lowest part of which we found 13 inches above the surface of the Fossake, and about 20 acres more laying in a slade a little higher up, on the north side, the lowest part of whose surface was 9 inches only above the Fossake; we also found that the only conveyance for the Till opposite this slade, was an artisticial cut or ditch, about 3 feet and a half wide in the bottom, and at this time quite dry.

7th. That having examined the several drains that fall into the Fossdyke, west of the Till, we find that the bottom of Dodington Drains (by its tunnel) is 1 foot  $6\frac{1}{2}$  inches higher than the surface of the Fossdyke; Thorney Drain bottom, near the tunnel, is 6 inches above the said surface of the Fossdyke; but the bottom of the said drain, which rises gradually at about \(\frac{3}{4}\) of a mile distance therefrom, is 4 feet higher than the same. The bottem of the first drain on Kettlethorpe Moor, near its tunnel, is higher than the furface of the Fossdyke by 3 feet 2 inches, the 2d by 1 foot 10 inches, and the 3d by 2 seet 2 inches; the bottom of the drain between Kettlethorpe and Fenton Moor, by its tunnel, is I foot  $1\frac{1}{2}$  inch, and that on Fenton Moor is I foot 7 inches higher, by its tunnel, than the surface of the said Fosselyke; and all the said drains rise considerably, as they advance into the land, and the faid land is also in general considerably higher than the bottoms of the said drains, so that it is evident that none of these drains, nor the lands through which they pass, can be affected by a rise of to inches in the Fossdyke above the surface it then had, viz. 4 inches and a half above Brayford Head.

## SCHEME for a general drainage and navigation.

1st. TO imbank both sides of the Fossdyke, where wanting, from Brayford Meer to the river Till, making all good, 5 feet higher than Brayford Head, (which, as the flood waters of the Witham are proposed to be kept out of this part of the river, will be sufficient) and cutting off all communication with Swan and Cuckoo Pools.

2d. To scour out and enlarge Sincil Dyke, from its lower mouth near Stamp End, to the place where the first or northernmost Gowt Bridge Drain falls into the same, bringing up the bottom upon a dead level with the bottom of the river Witham at Stamp End, making it 25 feet wide at bottom, with proper slopes. Then to scour out and enlarge the said Gowt Bridge Drain, from the said Sincil Dyke to the Witham, continuing the bottom thereof upon the same dead level, and 15 feet broad, with proper slopes or batters; and to continue the same underneath the Witham, by means of an underground turnel or fox, 14 feet wide and 3 feet deep, with pointing doors on the east end, and draw doors on the west end thereof: the river Witham to be entirely banked off from falling into this drain. A new drain of the same depth and capacity to be continued from the Fox to such part of Swan Pool as is as deep as the drain.

A drain

A drain of the same dimensions to be continued from Swan Pool to Cuckoo Pool. The ground taken out of the new cuts from the Witham to be disposed of bank-fashion, leaving forelands of 3 feet on each fide of the cuts.

3d. To strike out a drain from Swan Pool, or from any point of the drain before mentioned, between Swan Pool and Cuckoo Pool, that shall be in a proper direction for croffing the Fossayke, and to pursue the same to Bishop Bridge. This drain should be 14 feet bottom, with proper slopes, and to rise from the aforesaid dead level one foot between Swan Pool, or the point aforesaid, and Bishop Bridge; the said drain to communicate under the Fossayke by means of a subteraneous tunnel, or fox, of 12 feet wide and 3 feet high; the earth of the cut from Swan Pool to the fox to be disposed of bank-fashion, with forelands of 3 feet.

## N. B. A bridge will be wanting over this drain on Lincoln Common.

4th. To erect a lock with 2 pair of gates, upon the passage between Mr. Ellison's wharf and Brayford Meer, the gates to be pointed towards Brayford Meer; the whole to be built high enough to pen the water of the highest sloods of the Witham from slowing into the Fessavke.

5th. To scour out the river Witham where wanting, from Brayford Meer to Brace Bridge, and to embank the same on the west side, so as to be slood proof, and continuing the same on the south west side of Brayford Meer, to join the south side of the said lock; and to construct a similar bank on the north side of the said lock to the high land on the north fide of Fossdyke, making the faid banks 30 feet feat, 6 feet top, and 6 feet high; the river between Brayford Meer and Brate Bridge to be made at least 36 feet wide, and its bottom so deepened as to form a regular inclined plane one foot deeper than the present level of Brayford Head at that end thereof, and of the present depth at Brace Bridge. The bank to be formed partly from its back drain to feet wide at top, 4 at bottom, and 3 deep; the rest from the said widening or deepening the river, and to be placed 40 feet from the border of the river.

6th. To further scour out and enlarge the Sincil Dyke between the two lower mouths of the Gowt Bridge Drains, so as to be of the same dimensions as before specified for the lower part thereof, and from the lower mouth of the second or southernmost Gowt Bridge Drain, to scour out and enlarge the Sincil Dyke to its upper mouth at the river Witham, fo as to be 121 feet bottom, with proper flopes, and the bottom to be carried nearly upon a dead level from the said point to the river Witham. And in like manner and proportion the second or southernmost Gowt Bridge Drain to be secured out, and enlarged, from the said point to the river Witham, and to erect two staunches; one upon the upper mouth of the Sincil Dyke, the other upon the upper mouth of the said Gowt Bridge Drain, both opening into the river Witham: the Sincil Dyke staunch to be gauged to 1 soot 4 inches higher than the present level of Brayford Head; that is lower by 3½ inches than the highest part of the present bottom of the said drain, and the Gowt Bridge staunch to be gauged one soot 2½ inches above Brayford Head; that is one inch lower than the medium of the two Gowt Bridge Drain bottoms; the said staunch to have a clear waterway of 12½ feet each, and their cills to be laid as low as the bottoms of their respective drains.

7th. To erect a staunch at or near Lincoln High Bridge, on the west side thereof, the top of which to be gauged to 10 inches above the level of the present Brayford Head, and to be filled up with doors capable of allowing a clear water-way of  $15\frac{1}{2}$  seet at least, and the cills of these doors to be laid at least 2 seet 8 inches below the level of the present Brayford Head; after which, the said shoal of Brayford Head to be removed, and the whole contents of the river, between Brayford and Lincoln High Bridge, to be taken away as deep as the cill of the said staunch.

N. B. If instead of erecting the said staunch at the High Bridge, it be erected 100 feet to the west of the said bridge, with pair of doors pointing towards Brayford Meer, it will form the upper gates of a lock, for making a communication between the Fossake and intended navigation from the High Bridge to Boston.

8th. To scour out, enlarge, and embank the Till, from its junction with the Fossilyke at Haddow Bridge, to about 1 mile above the same, so as to be capable of sustaining and confining the greatest sloods within its banks, and to lay a small subterraneous tunnel of about 6 inches square under the same, to convey the down sall and soakage waters from the low grounds laying west thereof, into Burton main drain, by which they will be drained in conjunction with Carlton and Burton Fens, &c. without any annoyance thereto.

N. B. It is proposed that the said cut shall be at least 12 feet wide at bottom, and its banks 5 feet higher than Fossayke surface at low water.

9th. The gauged bar of Torksey Lock, (being 10  $\frac{1}{2}$  inches in height) to be removed, and the framed bar to become the gauge at Torksey.

toth. To erect a pillar of stone, in or by the side of Brayford Meer, whose top to be a foot 2 inches above the level of Brayford Head; to be so placed that the water thereof may slow sreely round and upon the said stone, with a set-off or conspicuous mark, I inch below the said top.

## The OPERATION of the foregoing Constructions.

1st. AS there appears, from the facts before stated, to be a fall from the surface of Brayford Meer to the surface of the river Witham, at the lower end of Sincil Dyke, of 14 inches in its common summer's state; and that from the lower end of Sincil Dyke to Stamp End there is a further fall of  $5\frac{1}{2}$  inches, chiefly owing to the obstructions of the river Witham between those two points, and also a yet further fall from thence to Baily's Sluice, of 10 inches; it follows, that whenever the Commissioners for the navigation between Lincoln High Bridge and Boston shall be pleased to execute this part of their undertaking, according to the act, that there will then be a much more confiderable fall obtained: or, in the mean time, if they will suffer the drainers above Lincoln to deepen the river between Stamp End and Sincil Dyke, that then this  $5\frac{1}{2}$  inches shall be added to the former 14 inches, fo as to make 1 foot  $7\frac{1}{2}$  inches fall from Brayford Meer to the lower mouth of Sincil Dyke. However, not to build this scheme upon the probable execution of another, we will, for the present, suppose every thing within that act to stand as it now does, still there will be a fall of 14 inches gained to Brayford Meer; and fince the general furface of the low grounds (before specified) that drain into Brayford Meer were from a foot to 18 inches above the furface of that meer, at the time of this view (Brayford Meer being then  $r = \frac{1}{2}$  inch higher than its lowest state) it follows, that there will be a fall of above 2 feet 6 inches from the general furface of the low lands to their out fall at Sincil Dyke tail; and as the flood waters of the Witham (which, for want of a sufficient discharge at Lincoln, have chiefly contributed to the overflowing of the same) will be held off by the proposed bank from Brayford Meer to Brace Bridge, there is no doubt but that the fall above mentioned will be sufficient for the general drainage of the low grounds aforesaid. It is true that someplaces, within the low grounds afore specified, lay lower than the general surface by several inches; but as the quantities so circumstanced are of no considerable extent, and as those very pieces will, by the execution of this scheme, be in better condition, as to drainage, than the greatest part of the low grounds now are, no reasonable objection can be drawn against the scheme in general from those particular places; for as to the low slade of the old Till, between Cuckoo Pool and Saxelby Pasture, it may be provided for by carrying the main drain through it, and will, of consequence, be most early in receiving benefit; and yet this slade will, at a medium, lay 2 feet, and its very lowest parts next Cuckoo Pool 19½ inches above summer's water, even supposing nothing was to be done below the tail of Sincil Dyke..

2d. With respect to the low grounds laying upon the Till, the Fossake water being raised to inches by the stanches at Lincoln High Bridge, will pen to inches upon the mouth of the said river in dry seasons, at which time it has no currency; but as we don't find any of those grounds will be affected thereby, except the small quantity before specified, and as in times of rains and floods, or whenever the water coming from the Witham would, in its present condition, rise 10 inches above its lowest state, (which, as has been shewn before, is the greatest part of the year) the Till will have a much better out-fall than it now has; for, in the first place, as the Witham waters (which at present rise upon them near 4 feet in times of floods) will be entirely shut out from the Fossayke whenever they would over-ride the same, by reason of the lock near Brayford Meer, and banks mentioned in the 5th article, as those waters themselves will be much sooner discharged than at present by the proposed stanches, as the gauge bar at Torksey Lock will be removed; and as it is also proposed to confine the flood waters of the Till with banks of a sufficient height and strength to sustain them till they are fully discharged into the Fossdyke, the low grounds on each side the said Till can then be no otherwise annoyed than by the down-fall and foakage waters, which will be very inconsiderable, as the earth for making the said banks is of a strong and tight texture, and as an ample provision for carrying off these down-fall and soakage waters is made by the subterraneous tunnel to be laid under the Till into Burton Drain, it follows, that upon the whole, the discharge of the Till waters will be considerably facilitated and improved, and the drainage of the low grounds under consideration, that lay thereupon, will be compleated.

3d. The grounds, west of Saxelby, which drain into the Foss, will in like manner have the surface of that river raised 10 inches upon the tail of their drains, in dry seasons; but as we find none of them that will be affected by that rise, (very little by double, nay even treble) and as the Foss will no longer be raised by the Witham sloods, and those sloods sooner run off by the gates of the proposed stanches, it will be kept at a more constant height, being no otherwise affected than by the influx of their own and the Till waters, which will find their way either into the Trent or Witham waters, as soon as either river is so settled as the Foss water will over-ride them; so that upon the whole, these

these lands being freed from the high floods, which principally annoy them, will be greatly benefited, and ought in strictness to contribute towards the making of the said lock and bank.

4th. The proprietors of lands above Brace Bridge will also receive benefit by this construction; for since there is 18 inches fall from the upper mouth of Sincil Dyke to Brayford Meer at ordinary seasons in summer, it is plain that an additional pen at the said meer will not sensibly affect the level of the water at the entrance of Sincil Dyke; on the contrary, when the widening and deepening of the River between Brayford Meer and Brace Bridge is performed, the water will then run off lower than at present; and since the tops of the staunches at Sincil Dyke and one of the Gowt Bridge Drains are to be lower than their respective bottoms now are, and the capacities of those drains greatly enlarged, it is manifed that though the staunches were never to be drawn at all, the water would have a better passage than it can now have; but as the preservation of the banks, proposed in Article 5. of the scheme, depends upon drawing the staunches, the proprietors of the aforesaid low grounds will not be wanting in drawing them when necessary, which will afford a great easement to the passage of the water far beyond any thing they have ever had: and, for the prevention of disputes between the land owners and navigators, it is proposed that whenever the water of Brayford Meer covers the stone pillars proposed in Article 10. that the gates of the staunches shall be drawn, or so many and so much as shall be found necessary to reduce the waters I inch below the top to the mark aforesaid; and whenever the water shall settle below the said mark, then the gates of the said staunches to be shut down, or so many and so much as to prevent its falling below the faid mark, which business will be regularly done by a person properly appointed and authorized for this purpose.

Bridge and Boston, will also be benefited by this scheme; for since the great object of that scheme was to preserve the living and flood waters, particularly those of the Witham, that scheme was to preserve the living and flood waters, particularly those of the Witham, that scheme was to preserve the living and flood waters, particularly those of the Witham, the readiest passage, instead of being spread over the sens and low grounds above Lintola, by which their force is broke, and a great part thereof evaporated by the sun and coln, by which their force is broke, and a great part thereof evaporated by the sun and winds. It is true that the Fossayke being kept up 10 inches higher, will expend some what more water in the passage of each vessel; but, on the other hand, the communication between the Fossayke and the Savan and Cuckoo Pools being stopped, the evaporation tion between the Fossayke and the Savan and Cuckoo Pools being stopped, the evaporation to a fair calculation, it appears that this evaporation is greatly more than sufficient to supply Vol. I.

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supply the difference of lockage, leakage, and soakage, that will probably arise from an increase of height of 10 inches in the Fossayke surface.

6th. This scheme will also be of great benefit to the navigation of the Fossayke, not only in giving the necessary quantity of water to render it compleat in all seasons, from the river Trent to Lincoln High Bridge, but in excluding such extra quantities of water, as in time of floods not only annoy the navigation, but the lands adjoining thereto, which inconvenience must have subsisted ever since this cut was originally made, and consequently must always have been the foundation of disputes and dissatisfactions between the navigators and land owners thereto adjoining; and upon the prefent scheme it appears that the interest of both parties coincide, it is greatly to be wished and hoped that they may as heartily join in the expence of executing the same upon an equitable footing; and lest any jealousy on the part of the land owners should obstruct the execution of project so much to their advantage, as supposing it more calculated to serve the navigation than themselves, we think it expedient to declare, that nearly the same advantages can be procured to the navigation as will be obtained in the scheme before specified, without prejudice to the present state of the land owners drainage, and that to accomplish as good a drainage, as is proposed by this scheme, will cost the land owners confiderably more, than if done conjunctly with the proprietors of the navigation.

## An ESTIMATE of the works mentioned in the preceding scheme.

Article 1st. To making good both banks of the Fossayke, from Brayford Meer to Saxelly	y L		d.
Pasture, opposite the Till,	- 403	15	0
Art. 2d. To scouring out and enlarging Sincil Dyke, from its lower mouth to the first	t		Q
Gowt Bridge Drain (including contingencies), -		15	8
To scouring out the first Gowt Bridge Drain, from Sincil Dyke to the Witham, and the	5		
contingency of under-pinning the arches under which it passes,	- 53		0
		12	0
To making a new drain from the fox to Savan Pool,	- 63	2	0
To making a drain from Swan Pool to Cuckoo Pool,	- 84	+ O	- 10
Art. 3d. To making a new drain from or near Swan Pool to Bishop's Bridge,	- 145	5 4	0
Carried of	over 119	8	8

	1		L. 5.		d.	
Brought of	ver •	11	90	8	8	
To making and laying the fox under Feffdyks,			90	0	0	
To making and anying the for the drain, and a waggon bridge for the		3				
Pywipe inn,			40	0	0	
Art. 4th. To constructing a lock between Mr. Ellison's wharf and Brayford Mee	r,	- 4	100	0	0	
Art. 5th. To scouring out and enlarging the river Witham, and embanking the	ame 📖 th	e				
west side from Brayford Meer to Brace Bridge, and to embanking Brayford I	Meer on th	ie				
fouth-west side, from the north end of the aforesaid bank to the lock, a	nd from th	ne				
lock across the high land in the north, including the south drain,	-	-	587	19		
Art. 6th. To scouring out and enlarging Sincil Dyke, between the lower me	ouths of	he				
Gowt Bridge Drain	4	~	12	0	0	
Scouring out and enlarging Sincil Dyke from the second Gowt Bridge D	rain to t	he				
Witham, and the contingence of under-pinning Bargate bridges,		-	63 %	5	(	)
To scouring out and enlarging the second Gows Bridge Drain, from Sin	icil Dyke	to				
and the contingence of under-pinning the arches under wines	I It panes	,	42	10		•
denotes one of the upper mouth of each of these drains, at	. I DOM CO	City	360	0		0
Art. 7th. To constructing a fixed stanch, with draw-door, at or men the Hig	b Bridge	at				
			200	0		0
To scouring out Brayford Head, and deepening the river from Brayford M	eer to Lin	coln				
the state of the state of the walls.			195	9	>	0
and aplarging the Vill, from Haddew Bridge one min	e upward	s, lo				
Art. 8th. To deepening and enlarging the ranking frong and effectual las to be 12 feet wide at the bottom, and making frong and effectual	banks on	each			,	
and a contract the law water in the collection			168	•	>	Q
To making and laying a subterraneous tunnel under this dyke and banks, 6	inches sq	DALC				
			4	•	3	
To making a catch-water drain and bank on the lower fide, at the upper	er end of	this				
To making a catch-water drain and bank on the fame, which will conew cut, to reach the high land on each fide the fame, which will conew cut, to reach the high land on each fide the fame, which will conew cut, to reach the high land on each fide the fame, which will conew cut, to reach the high land on each fide the fame, which will cone the fame, which will be cone the fame that the	nduct all	the				A
new cut, to reach the inguinant		-	8		5	•
Art. 9th. To taking away the gauge-bar Torkjey Lock,		-			5	0
O' - A GONG DILLAF IOI - VAUVE HOLEIN III - SO	-	•		5	0	0
Art. 11th. To supervising, and unforeseen contingencies, at 101, per cent.	-	-	35	3	_	_
Art. 11th. To supervising, and address		_	-0.	6	. 2	2
		£.	381			
00-1-16 1760		T	Car	PT 3.T 1		
Doneaster, October 16, 1762.		JOHN				
		J. SM	EAT	02	•	

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We come now to give an answer to the following question, communicated to us by Mr. Amcorts.

"Mr. Gollman desires to know if the Sincil Dyke and the Gowt Bridge Drains were to be scoured out and deepened to the depth of the new intended river below Lincoln, with gates erected at the upper end 2 inches higher than the present height of Brayford Head, a channel to be made from those places into Brayford Meer, to communicate with the Fossdyke; the gates to be opened at the time of floods, the shoal at Brayford Head to be removed, and gates or a ware to be erected by the side; the top of which to be 10 inches lower than the present height of Brayford Head, with a waste board to be placed thereon in dry seasons; what effect such a scheme would have on the Fossdyke navigation?" The scheme here proposed, in some respects, is the same as the scheme proposed by us, as before specified, but with this essential difference, that our scheme proposes to give the Fossdyke navigation an addition of 10 inches constant water above its lowest state, and a compleat drainage to the lands; the other to keep it constantly at its lowest state, with an impersect drainage of the lands.

From the time the rains usually fall in September or October, to the running off and evaporating the flood waters in May, the Fosfdyke navigation is generally as compleat as ean be wished for; but were the flood waters run off by the proposed gates as they come down, the Fosfdyke would never be above its lowest gauge, except at the top of high floods; which, as they would be uncertain, would be of little use to the navigation: for as Brayford Head is proposed to be reduced to inches, except in dry seasons, this would constantly run off the common current waters; and perhaps often more than that after the gates had been drawn, so that at those times the Fosfdyke would be reduced to a lower state than it ever can be at present, all which in consequence would be a great detriment thereto; besides, no man as a navigator would chuse to subject his water to the mercy or misconduct of others, or the want of necessary repairs of gates, stanches, or other works, without any prospect or probability of any advantage arising therefrom.

And with respect to drainage, the scheme proposed by the aforesaid question is extremely imperfect; almost all the requisites for a compleat one being omitted, that is to say, the necessary imbanking of the rivers, &c. to keep out the flood and barrier waters, and the proper means of carrying off the downfall and soakage to a surface sufficiently below the soil of the lands to be drained; for nothing more is thereby proposed towards accomplishing these great ends, than forming stakes to ease the flood waters, (which is as fully and amply provided for in our scheme as in this) but very far from totally removing

moving their effect upon the low lands in question; so that, after the execution of such a plan, the low grounds of Boatham, Skellingthorpe, Saxelby, Lincoln, Burton, Carlton, &cowould yet be liable to be overflowed in all wet seasons, and in dry ones the proposal itself points out no advantage in drainage.

Doncaster, Oct. 16, 1762.

JOHN GRUNDY.
J. SMEATON.

Concerning the drainage of the low grounds of Torksey and Fenton, which drain by Torksey Bridge Sluice.

As the drains of those grounds have no communication with the Fossake, till below Torksey Lock, their out-fall is in effect into the Trent, and therefore it is of no concernment to them what the height of the Fossake surface is between Torksey and Lincoln.

Torksey Bridge Sluice (the out-let) lays on the south side of the Fossayke, and also the drain leading thereto, which extends eastward about a furlong, and there divides, one branch turning to the right through Fenton Moor, the other to the left through Torksey low grounds, which laying on the north fide of the Fossayke, communicates by means of a subterraneous tunnel or fox, each drain having a separate suice near the point of partition, which shuts reciprocally in case either water should over-ride the other. Each of these drains receives the down-fall waters from an extensive tract of country, and in consequence, in times of great rains, when the Trent is so full as to keep shut the doors of Torksey Bridge Sluice, those waters overflow their respective drains, and consequently the lowest lands near their out-fall, and if the rains are violent and lasting, and the Trent continues high, as it sometimes does for weeks together, the waters, all this while accumulating within, rise to a great bulk and height. As therefore the cause must always remain, the effect will do so too; the only thing that can be done, in the present case, is to give the water a passage sufficiently free, that whenever the Trent becomes lower than the waters within, they may run off as soon as may be. Those ought to be the views of them who undertake the drainage of those tracks of land. The only question that relates to the Fossdyke is, whether the proprietors thereof have made provision for difcharging those waters as amply as the proprietors of lands have made for themselves to bring the water thither \*.

The fluice at Torkley Bridge, and the fox under the Foffdyke, are works constructed by the undertakers of the Fossayke; the fluice at the tail of Fenton Drain, and that at the tail of Torksey Drain, leading into the fox, are old works constructed by the land owners to serve their own occasions. The sluice at Torksey Bridge consists of one arch or tun of 7 feet wide, which having a staple-post of 1 foot wide in the middle, forms it into 2 apertures of 3 feet wide each, which are shut by two falling doors; the sloor of this fluice lays lower than Fenton Sluice by I foot 9 inches, lower than the fluice entering the fox by I foot, and lower than the lowest lands to be drained thereby 2 feet I inch. The width of Fenton Sluice is 2 feet II inches; the fluice leading to the fox consists of two doors, which are 2 feet 1 inch wide each. The width of the fox is 2 feet 10 inches by 2 feet high, and the entry thereof lays 8 inches lower than the threshold of the sluice adjoining. Ist. The question is therefore, whether Torksey Bridge Sluice is equal to the capacity of Fenton and Torksey Fox Sluice taken together, in point of discharging water; and, 2d, whether the capacity of the fox is equal to the capacity of the fluice leading thereto. Having subjected this matter to calculation, we find that at a mean height of the flood waters upon Torksey (which is the lowest lands) that Torksey Bridge Sluice will run more water than Torksey Fox Sluice and Fenton Sluice put together, by above 200 cube feet in a minute, which arises from its laying so much lower; but that, in the like case, the fox will not run so much water as the fluice adjoining thereto; but that if another equal tunnel is thereto added, that the capacity of the two will exceed the capacity of the said sluice by above 500 cube seet in a minute. We therefore recommend it to the Fossayke proprietors to add another fox of equal capacity, or to double the capacity of the present; but as we are of opinion the foundation of the grievance does not fo much confift in want of capacity in the fox to discharge the water, as in the sluice itself to run it off, low enough, we are of opinion, that at the same time the capacity of the fox is enlarged, that the land owners should lay the threshold of this sluice as low as the out-fall sluice at the bridge, and that the entry into the fox should be made conformable thereto. In this case, the mean capacity

for discharging water will not only be doubled, but with the advantage of running it r foot lower than at present, which will be above 2 feet lower than the lowest lands that drain thereby.

N. B. It must, however, be considered, that it is but lately that a new tunnel of 2 feet wide at Harrow Head Bridge has been added; the whole capacity of that bridge was before that time only one tunnel of 2 feet 2 inches wide, the paved floor whereof lays at least fix inches higher than the sluice at the fox; and as the bulk of the water that comes to that sluice comes through this bridge, it must be acknowledged that the capacity of the fox to discharge water at the time it was made was superior to the capacity of this bridge to let down the water to it.

The meeting of the Torkfey and Fenton waters, in a direction nearly opposite, is a manifest incongruity; but as the place of meeting is pretty deep, and wider than the rest, it forms in some measure reservoir common to both, and, if perfectly so, it would signify little in what direction the water comes in; but as it appears to us, that as the land drains and sluice lay lower on the Torksey than on the Fenton sides, that the Fenton waters will generally over-ride the Torkfsy: this will deferve a remedy that will also cure the other desect at the same time. We therefore propose that a new tun of 4 seet wide and 3 feet high, with one door, to be added to the present suice at Torksey Bridge, on the fouth side thereof, and making a partition between the old and new tuns, and to bring the present common drain in an oblique direction to the new tun, and to carry a new drain from behind the said partition, from the old sluice to the tail of the fox, stopping the present communication near Fenton Sluice; by these means the waters will be kept quite separate, which will be a great improvement to the present drainage of the low grounds under consideration; and it will lay the foundation for compleating the drainage thereof, as far as nature will allow, in our opinion, the land owners ought to be at part of the expence of the aforesaid new suice and drain. An obvious mistake has also been committed in turning the tail drain leading from Torksey Eridge Sluice into Fess, below the lock, at a square elbow; but if it be considered, that this drain, being wider than the clear water-way of the fluice by three feet, and deeper than the floor thereof, the velocity of the water is so much less on account of a greater capacity, that the ill effect of this inconsistency is not, in reality, so great in the present case as it may seem; however, as this drain must be widened near the sluice, on account of the new tun, to give a freer passage to the water, and to remedy this defect both at once, we advise the turn of the said drain to be made by a quarter round instead of a square elbow. JOHN GRUNDY.

<sup>•</sup> In constructing works by act of Parliament, if ample provision is made for the preservation of private property, to the satisfaction of the proprietors at the time, that if afterwards those proprietors extend their views in order to improve their property, that the public undertakers at their own expence to make all such alterations in their works that the land-owers should think sit; if this was the case, a public undertaker would never know when he had done.

To the gentlemen assembled at a general meeting on the 2d day of September, 1782, for considering of a plan of improvement of the navigation of the river Fossayke, and for improving the drainage of the lands on each side the said river.

GENTLEMEN,

SINCE my arrival at Lincoln on Thursday evening last, (as desired by Mr. Lyon) I have diligently employ edmyself, in conjunction with Mr. CARLTON, and Mr. PILLEY, agent for Mr. Ellison, who were appointed to conduct me, in reviewing the different parts of the extensive scheme of drainage and navigation, that was formed by Mr. Grundy and myself in the year 1762, in order to prepare myself to assist you, gentlemen, in the reconsideration thereof.

It is a subject indeed so extensive, that the time has been sully employed in going over some of the most material and leading parts thereof, and it will necessarily take a further length of time to enter into that accurate and digested consideration that it had from Mr. Grundy and myself at the time abovementioned, being now 20 years ago. But, as upon this revisal, I find a very striking difference in the situation of the leading circumstances attending this business, I think it necessary to lay those open to your consideration, because, unless some means are sound, by which the impediments, that since that time have been placed in the way, can either be removed or avoided, it seems fruitless to enter into any scheme for the general drainage of the low grounds west of Lincoln: for it does not appear to me, that as things now stand, any such material improvement can be made therein, as shall be likely to answer the cost of doing it.

When the scheme of 1762 was under consideration, the Witham navigation act from Lincoln to Boston was then substitting, with a clause therein, that no staunch or land-door should be erected between Washingborough Ferry and Lincoln High Bridge, which should not be at least 2 feet below the lowest grounds in Canwick Ings, as by reference to the act will more sully appear. At present, I find a lock and a staunch below the lower mouth or out-sall of Sincil Dyke, which by the former scheme was to be the out-sall of the drainage waters of the lands west of Lincoln into the river Witham, the top of the gates or doors of which staunch is higher than the surface of the said lowest grounds of Canwick Ings, and consequently they are, as it appears to me, full 2 feet higher than according

according to the said clause they ought to be, (the doors or gates of the lock being still higher) and the top of the gates or doors of the said staunch being sull as high as Brayford Head was in 1762. The sall for the drainage waters from Brayford Meer to the lower mouth of Sincil Dyke is now taken away and lost, the water being now so near upon a level at the two said points, as to be totally insufficient towards any material improvement in point of drainage.

In order, therefore, to recover the fall for the proposed drainage waters that then sub-sisted, it appears to me absolutely necessary, either to remove the said staunch, whereby the waters may have their natural descent in its ancient course through the city of Lincoln, or to carry the out-sall drain so far below the limits of the Sincil Dyke as to pass through some part of Canwick Ings, and fall into the present course of the river Witham below the said lock and staunch; that is, where the same, on mature consideration, shall be deemed the most eligible.

The latter way appears to me at present preserable, not only as it would not intersere with the present navigation, but the drainage waters would be less liable to be over-rode by the living waters of the Witham.

I am, Gentlemen,

Your most humble fervant,

Lincoln, September 2, 1782.

J. SMEATON.

To the Gentlemen that attended a general meeting on the 2d day of September, 1782, at the Rein Deer at Lincoln, for confidering of a plan of improvement of the navigation of the river Fossilyke, and for improving the drainage of the lands on each side of the said river.

The REPORT of JOHN SMEATON, Engineer, upon the improvement of the navigation of the river Fossake, and for improving the drainage of the low lands on each side of the said river.

In the year 1762, Mr. GRUNDY and myself were employed by Mr. Ellison to form a scheme for the improvement of the Fossayke navigation, and at the same time to improve the drainage of the low grounds west of Lincoln, of which business we acquitted ourselves by our joint report, dated the 16th of October of that year; contrariety of opinion among the parties interested at that time prevented the execution of the scheme then proposed.

In August last I was invited to reconsider the said scheme, and to assist the gentlemen interested in this business in sorming such a one, as at this time should be useful and agreeable to all parties, and to attend their public meeting at Lincoln for that purpose upon the 2d of September last, which accordingly I did.

On reviewing the subject previous to this meeting, I perceived that upon supposition of the best possible drainage, compatible with the improvement and even subsistence of the Fossible navigation, that the scheme then proposed appeared now to me to be very complete upon the circumstances and situation in which things then were; but that at present, the case is so very much altered, that the very ground and soundation upon which we built the principal merit of the scheme, so far as it related to drainage, is now subverted; for the ultimate drainage of all the grounds in question being into Brayford Meer, and as at that time there subsisted a fall in dry seasons in summer from Brayford Meer, through the city of Lincoln, to that part of the river Witham where the tail of Sincil Dyke salls into it, of 14 inches, and a surther sall then of 5½ inches more to Stamp End, and which was still greater down to the point where Bailey's Sluice Drain salls into the same, it appeared to us, that the addition of this sall to the low grounds that then drained into Brayford Meer, when judiciously managed, would make the drainage thereof very compleat. Nor were there at that time any reason to sear the loss of this fall, but

rather an expectation of gaining more; for though the act of parliament for draining the lands, and making or improving the navigation from Lincoln High Bridge to Defior, had then passed , yet as the advantages that might in future possibly result from this fall to the city of Lincoln, and low grounds west thereof, were guarded by a clause, enacting that no staunch or land door should be erected between Washingborough Ferry and Lincoln High Bridge, which should not be at least 2 feet lower than the lowest grounds in Canvoick Ings, there could then, in regard to this fall, be no apprehension of difficulty; but contrary thereto, on this view I found a lock below Stamp End, now called Lincoln Lock, accompanied with a staunch, erected across the river Witham, abreast of the said lock, and consequently below the tail or out-fall of Sincil Dyke, into the said river; the top of the faid doors of which staunch was not only higher than the medium surface of the lowest grounds in Canwick Ings, and therefore full 2 feet higher than according to the faid clause they ought to be, but also higher than the natural staunch of Brayford Ilead was in the year 1762, and occasioned a pen of the water in Bravford Meer, higher by 11 inch than it was at that period: in consequence, as in this state of things Brayford Meer is rather higher than lower than it was, and the fall that might have been required totally taken away and destroyed, it follows, as things now are, (Brayford Meer being still the ultimate out-fall of the drainage of all the lands in question) that no material improvement can be made therein.

These consequences I did myself the honour of laying before the gentlemen assembled at the meeting of the 2d of September last, and withal observed, that unless either Lincoln Lock and Staunch, as it now stands, can be removed, or a new out-sall procured for Sincil Dyke, so as to fall into the Witham below the said staunch, it will be to no purpose to think of any schemes of drainage that will be likely to be attended with benefit equal to the expence.

These matters being sully considered by the gentlemen present, and seeing difficulties in either way, and it being the general sense of the meeting, that it would be a considerable improvement to their low grounds, if they could more early in the spring be siderable improvement to their low grounds, if they could more early in the spring be cleared and ridded of their water, without destroying the navigation through Lincoln, I then observed, that on supposition Lincoln Staunch and Lock was removed still higher up the observed, that on supposition Lincoln Staunch and Lock was removed still higher up the stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be stream from its present place.

This scheme, after fully and deliberately considering, I now beg leave to propose.

The lands at present under consideration are the general reservoir of the waters that in great floods are brought down by the river Witham from the upland country, through a course of above 40 miles, the passages for which through Lincoln, relative to the fall it has, are at present so very inadequate to the discharge of this water as fast it comes, that it extends over a vast tract of ground of many miles square.

In the year 1762 it was known to have rose above its summer drainage height about 4 feet perpendicular, but upon this view this water, from marks that were shewn me, its height had been more than 5 feet 9 inches above the former mark, which shews that the banks necessary to restrain and carry off so great a body of water as fast as it comes would be required of fuch heighth and strength, that I am of opinion (with the land owners) it would be not only very difficult and very expensive to confine, but be matter of objection to the drainage of the lands upon the Witham below Lincoln.

In a dry season the lands in question become compleatly drained by the present outlets, but as the ultimate level of Brayford Meer, at which the fresh waters of the Witham can be discharged, is but a few inches lower than the lowest grounds proposed to be drained, when the top waters are so much run off, as that the drainage is almost compleated, the quantity capable of being then discharged but so little exceeds the influx of the Witham from the higher country, that was it not for the joint action of the fun and winds, the furface of these lowest tracts would never become dry, so as to be capable of any good produce of vegetation; but if when the top waters are run off, and the whole furface reduced to the level of the present natural banks of the river and aqueducts, a discharge is provided, that now cannot run for want of level or fall, a very moderate discharge (that would fignify but little in respect to the running off of the top waters) continuing to operate by itself separately, and independently of the river Witham, and appropriated wholly to the discharge of such internal waters as are left behind, after the flood waters are reduced within their natural banks; I say, such internal dead waters would very speedily be discharged when all communication with the living waters were cut off, though this new and separate discharge was not above half as much as the current of the river Witham in dry seasons.

It is obvious, that a meer removal of Lincoln Lock's staunch would not fully effect this business, even though Brayford Head was fully cleared, and the channel deepened through Lincoln, because still the Witham water would be obliged to pass through the

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fame channel; that is, it would pass through the preserable channel, in point of fall, while in common, and therefore would interfere with and over-ride the drainage waters at the very pinch when the drainage was wanted to be compleated.

Furthermore, if the Fossayke navigation was supplied with water by an aqueduct from an higher part of the river Witham, independent of Brayford Meer, and the out-lets of all fuch grounds as drain into Fossayke east of Saxelby, or into Brayford Meer, banked off, (making Fossdyke itself a means of discharging the top waters when the whole country is over-pressed) then Brayford Meer may remain at its present height, and all impediments be removed between Brayford Meer and the first lock towards Boston, as low as to the floor of the water-way under Lincoln High Bridge, which would render the navigation through Lincoln much preferable to what it now is, as there would be 2 feet depth of water at fuch times and places where now there is no more than one.

#### THE SCHEME.

1st. To remove the lock called Lincoln Lock and its staunch, from its present place below Stamp End, to above the tail of Smeil Dyke, where there is a commodious opening to receive it, as will appear from a sketch of the manner in which it may be placed.

2d. To deepen that part of the river Witham that lays between the present place of the staunch, and the place where it is now recommended, so as to make it passable for any boats that can now come up to Lincoln Lock, and which will not require a deepening of above half a foot at a medium.

3d. To scour out Sincil Dyke to as great a width as it has ever originally been, from its tail or out-fall into the Witham, to the tail of the great Gowt Drain, bringing up its bottom upon the same dead level with the bottom prescribed in the last article, as necessary for navigation, and to as great a width as it will carry, after allowance of sufficient slopes.

4th. To dyke and scour out the great Gowt Drain to the greatest width it will bear, and still bring up the bottom upon the same dead level as prescribed for Sincil Dyke; but instead of opening a communication with the river Witham, to continue the said drain under the river by means of an under-ground tunnel four feet wide and four feet high clear water-way, with doors pointed towards Sincil Dyke. The floor of this tunnel to be laid fo much deeper than the bottom of the Great Gowt Drain, that the river Witham may run in high as that the river Witham may pass over it without raising its lursace, in its ordinary or extraordinary state, upon a width of at least 30 feet. The west side wall next the low lands to be raised to a competent height to prevent the Witham's waters, in time of sloods, from cascading over it; but the height of the east wall to be raised only one foot above the ordinary surface of the Witham, so that when there is a swell in the Witham above that height, it may cascade over into this Govet Drain, which will then as as a state, according to its present intent, and make its way by Sincil Dyke to the Wuham.

mouth at the river Witham, yet not to make an open communication with the river; but to prevent the river in dry times from taking its course that way, and to give it a competent passage through Sincil Dyke as a staker drain, (to which use it has been apparently intended in its original formation) to construct a weir of 60 feet in length upon the crown, ranged along the east side of the river Witham, which, being immediately collected into Sincil Dyke Drain, can run no more water in high sloods than the drain will and ought to contain: in time of dry seasons to be about one inch above the water's surface of the river, so as just to pen in all the water thereof, and upon a fresh rising above that to discharge a competent quantity, upon a moderate additional height, in virtue of the length of its crown.

6th. To effectually scour out the lesser Gowt Drain, and in like manner as the entry into Sincil Dyke, to be shut off by a weir of 45 seet long in the crown, conditioned and operating as Sincil Dyke in proportion to its size; but to allow for the natural fall of the river from Sincil Dyke to the entry of the little Gowt Drain, this weir to be gaged 1½ inch lower than the former. And N. B. it will be proper to give all possible freedom and effect to these 2 staker drains, because the Great Gowt Drain will not now serve this purpose except in floods.

7th. A drain to be carried from the faid tunnel, at the head of the Great Gowt Drain, to Swan Pool, and to pass by or through the same, as shall be found most convenient and practicable in the execution; to be of 12 feet bottom, with proper slopes, and still carried on upon the same dead level. From thence the drain to pass forward upon a 10 feet bottom to a proper place, to divide into two branches; one tending towards Cuckeo Pool, and the interior parts of Skellingthorpe; the other towards a proper point of the Fossayke, to receive the Burton and Carlton, &c. waters, from Bishop's Bridge, by a subterraneous tunnel under the Fossayke; all which said drains are to be carried on upon the same dead level as before prescribed.

8th. A fubterraneous tunnel to be laid under the Fossake, to communicate the water from Bishop's Bridge, of sufficient capacity to run the drainage waters without material loss of fall after the top waters are discharged; but as the laying a tunnel of this kind, the top of whose arch must be so deep below the common surface of Fossake as to clear the navigation, the construction of such a tunnel by the ordinary means in brickwork would require so much length of time as to be a great loss of tolls to the navigation, which, together with the actual expence, would lay too great burthen upon the scheme I am proposing; I would therefore recommend the tunnel under the bottom of the navigable river to be made of cast iron. This to be made in proper lengths with stanches, by which they can with bolts be readily joined together; and I expect that a clear iron pipe of 2 feet 6 inches diameter would be very competent to this business, but that of 3 feet would put it beyond all doubt.

9th. From this tunnel a drain should (still upon the same dead level bottom) be carried to Bishop's Bridge, and that bridge rebuilt correspondent to such depth, the width of the drain's bottom to be 9 feet, and the tunnel of the bridge correspondent; from thence the drain to be carried forward, as a private work, into Burton and Carlton lordships; but still I would recommend, that whatever width may be taken for the bottom, that it be carried on upon the same dead level till it comes to the pinch of that drainage, which, according to Mr. Grundy, is in South Carlton lordship, and that the ground in the lowest stade there is no more than 147's inches above Brayford Head, as in the year 1762, that is 870 inches above Brayford Meer, as I found it this year, 1782; from 1762, that is 870 inches above Brayford Meer, as I found it this year, 1782; from thence the main drains, as well as side drains bottoms, may be allowed to rise at discretion.

10th. I would recommend a drain to be continued from the former, at or near Cuckoo Pool, through Skellingthorpe, by way of the low flade of the ancient course of the Till, into Saxelby Pasture, till opposite Saxelby Meadow, on the north side of the Fossayke, diminishing from a 7 feet bottom at Cuckoo Pool, to a 5 feet bottom at the said point in Saxelby Pasture; but still continuing the same dead level.

11th. Between Mr. Ellison's wharf and Brayford Meer to construct a navigation lock, with gates pointed towards the Fossayke, shutting up all other communication between. Fossayke and Brayford Meer, except by a weir, as per next article.

12th. To make an aqueduct of 10 feet bottom, to take its water at the river Witham, just above the Great Gowt drainage-tunnel, and to pass to the Fossoyke at some convenient

convenient place opposite to or west of Mr. Ellison's wharf, in order to supply the Fostdyke with water; and, at a certain height, a weir or over-fall to be constructed, that all redundant water beyond the supply of the Fossayke navigation may be returned inter-Brayford Meer, and so go to Boston; this ought to be 40 seet in length upon the crown.

N.B. This aqueduct necessarily intersecting the drain prescribed in the 9th Article, is to pals it, by a continuation of the tunnel, as an aqueduct bridge, to convey its water in a separate passage over the drain, and to be well imbanked on each side, so that it be never overflowed till the country is under water.

13th. To make a provisionary navigable staunch at Brayford Head, the gates whereof to be gauged to the same height that Brayford Head was in 1762, that the navigation into and upon Brayford Meer may not be dependant upon the staunch at Lincoln Lock, and the whole passage cleared from Brayford Meer to Lincoln High Bridge, as deep as the floor of the passage of the said bridge; and then if the trustees for the navigation from Boston to Lincoln think proper, in like manner, to clear away to the same depth east of the said bridge, there will be a clear navigation from Brayford Meer to the fea, equivalent in all parts passing Lincoln to that under Lincoln High Bridge.

N.B. In time of floods the gates of the Brayford Head staunch must be set open, as well as the doors of the Lincoln Lock staunch, for relief of the country west of Lincoln, in running off their top waters, as I am informed is very properly the present practice; but it should seem that the opening and shutting of these doors should be within the direction of the magistrates of the city of Lincoln, who, being most central, will more readily be apprifed of, and fee the necessity of the country.

14th. That for the general relief of the country west of Lincoln, and the more speedily to get rid of their top waters, which, as before, will continue to overflow the whole Country in the winter season, it will be very proper to embrace Mr. Ellison's proposition of granting liberty for a side weir to be constructed of a proper height at Torksey; so that a part of the top waters may be run that way into the Trent, when the level of the Trent will admit thereof, as it often at such times does. This weir, however, should not be too low, that the Witham fens drainers may have no reasonable complaint of losing water to keep their out-fall clear; nor should it be too high, because, if so, it will be of little use in answering the purpose for which it is made; but it should be of considerable extent in length upon the crown, that when it does discharge it may do it with effect. It appears to me, that if it is made 100 feet upon the crown, its height 6 inches below the

gauge bar of Torksey Lock, that is about 41 inches higher than the framed bar, it will answer all these purposes. This would be easily constructed, extending 100 feet eastward from the east end of the wharf wall, on the fouth side of Fossayke; but as its discharge cannot be permitted to over-ride the Fenton Drain, the present south bank of the Fossayke must be carried forward from the east end of the weir, between the weir's water and the Fenton Drain, quite up to the walls of Torksey Bridge; and to be made proof, so that the water shall never, after passing the weir, slow into the drain: and, furthermore, as the Trent floods frequently greatly over-ride the Fossdyke waters, even in their highest condition, it will be necessary that the water of this weir should be conveyed to Trent by a separate passage, intermediate between the lock and Fenton Drain, whose out-let must be shut by doors pointed towards the Trent. A proper capacity for this passage will be about 8 seet wide, and 5 seet high in the clear; but its threshold need not be laid so low that of Fenton Drain by a foot, so that as the foundations may be compleatly in the dry, it will not be so expensive as sluice-work often turns out to be.

15th. The living waters of the Till can evidently have no other out-fall than into the Fossdyke. The Fossdyke will be, by the proposed mode of supplying it with water from the Witham, held about 10 inches higher in very dry seasons than it formerly was; but if the Till, which has now little or no banks, was imbanked to inches, it would at all times be as competent to hold in the living waters as now, before the adjacent meadows were overflowed. But let us suppose it imbanked 2 feet, yet as the ground is low on both sides, but the lowest in Saxelby Meadow near Haddow Bridge, which then would not be more than 2 inches above that advanced height of the surface of the Fossayke, this would necessarily be too small an elevation of surface for these grounds ever to have competent drainage; but as they are but of small extent, when the living waters of the Till are so imbanked from them, a very small tunnel, with a competent fall, would effectually drain them; for this purpose I would propose to drain them by means of a leaden pipe of 5 inches bore, under the Fossdyke, into the drain proposed to be carried on the south side to Saxelby Pasture, laying also a small common tunnel under the Till to communicate a few acres of drainage from Haddow Meadows (which are the higher) into Saxelby. I preser, in this case, a leaden pipe, because it may be lowered into the water, and compleated, without ever interfering with the navigation at all. Or, if better approved, these meadows near Haddow Bridge may drain by a communication across the Till as aforesaid, (but from Saxelby into Haddow) and then by way of South Carlton to the great iron tunnel proposed in Article 8. OPERA-

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## OPERATION of the preceding scheme.

UPON my late view I found the pen of Lincoln Lock to be good 14 1/2 inches, with a competent fall for the current waters of the Witham through Lincoln and the Slaker drains, which I estimate at 11 inch more, that is in the whole good 16 inches; it is therefore manifest, that by the means proposed these 16 inches will be added to the natural fall of the drainage-waters that they now have into Brayford Meer; and the living waters of the Witham will then get discharged as they do now, and the internal drains being carried upon dead level bottoms, and dug below level till they get to the pinch of their respective services, they will perform their drainage down to the dead level of their outfall, in which case the point in South Carlton, that is reported to have had but I foot 21 inches elevation above Brayford Head, as it was in 1762, that is, but 81 above the level of Brayford Meer, as I found it the 31st of August last, will then have a fall of 2 feet I inch from the faid furface to its out-fall; and the low slade in the west of Skellingthorpe, that was the same day 6 inches above Fossdyke, (that is above Brayford Meer) will have a fall of 1 foot 10 1 inches to its out-fall, which will fully suffice for a perfect drainage in seasons moderately dry; but this being somewhat less than what has been esteemed compleat, I must beg leave in this place to take notice, that formerly, when it was not the practice to dig drains below the dead level of the out-fall, nor to carry their bottoms upon a dead level, but rifing towards the country to be drained, it was then held necessary to have a calculation that the utmost reduction of the water within soil should not be less than 2 feet. But the experience of the last 20 years has informed me, that where measures are taken to make the drains readily and speedily, (after the top waters are discharged) reduce their water's furface one foot within foil where it is tolerably firm, will form a very effectual drainage, and in soils less firm 18 inches done speedily will be full as effectual as an ultimate of 2 feet performed in that flow lingering manner which is the consequence of shallow drains, containing no competent body of water in the bottom, to be moved; for let the body be however great, gravity acting with equal force on every particle, the fall being the fame, will give every particle an equal velocity, and consequently the whole. Now, as I found Saxelby Meadow was elevated above Fossdyke 11 inches, it will, by what is proposed, be elevated 2 seet 3 inches above its out-sall, and therefore several inches to spare to give its water a competent velocity through the pipe.

Hence it is evident, that the drainage of all the low grounds will be compleated in all summer seasons, but will, as at present, be subject to be overslowed by the great winter's sloods, but whose top waters will be more speedily run off by the discharge

into Trent, and by the drainage waters running off with a good current, when at prefent they do not run at all.

By avoiding all imbankments of the Witham, and the waters allowed to spread as at present, all oppression of the drainage lands east of Lincoln is avoided; and in running off their ultimate drainage waters of the west country more speedily, the east country will be greatly benefited, because they will be sooner ridded of their western waters coming upon them; for this must be laid down as a rule, that in like circumstances, the lands downward upon a stream can never expect to drain prior to those above them, and therefore the sooner the waters of those above are discharged, the sooner the drainage of the whole will be compleated.

The navigation east of Lincoln High Bridge will be greatly benefited, because Brayford Ilead being cleared away down to the level of the stoor of Lincoln High Bridge, will give 1 foot more water than at present, and the like advantage would take place quite through Lincoln, if the Witham, east of the said bridge, was suitably cleared.

The Boston out-fall will also receive benefit, notwithstanding that some of the top waters will be discharged into the Trent, because it can be no advantage to a country already oppressed with water to receive an addition; and as the follow of the living waters will be continued in more full body after the extreams are gone, the powers of scouring will be continued to a period, when otherwise they would have ceased.

In order to state the advantage to the Fossayke navigation, and its relation to the drainage of the country, it will be necessary to ascertain some fixed points of level.

In the year 1762 it was afcertained by Mr. GRUNDY and myself, that when there was  $4\frac{3}{4}$  inches depth of water over *Brayford Head*, the surface was then  $5\frac{1}{4}$  below the top of the Aisler course of the Lincoln stone in the face of Mr. Ellison's wharf, consequently the said course was at that time 10 inches above the natural staunch of Brayford Head.

On reviewing the same in the year 1782, I found I foot water upon Brayford Head, (as held up by the staunch of Lincoln Leck below) and at that time its surface was 4 inches below the said Aisler course, consequently the Aisler course 16 inches above Brayford Head, below the said Aisler course, consequently the Aisler course 16 inches above Brayford Head, as it now is; that is, Brayford Head in 1782 was lower by 6 inches than in the year as it now is; that is, Brayford Head in 1782 was lower was 1\frac{1}{4} higher. I would there1762, and the surface of the water of Brayford Meer was 1\frac{1}{4} higher. I would there1762 and the surface of the water of Brayford Weer was 1\frac{1}{4} higher. I would there1762 and the surface of the water of Brayford weir to pen the water in Fossake, and over

over which the surplusage shall fall into Brayford Meer, to be 5 inches higher than the said Aister course, which in fact will be all that will be gained to the Fossayke; because it is said, and I suppose may be proved by evidence, that when this wharf was built about 40 years ago, the said Aister course was compleatly covered with water, that stone being of the reputed quality not to bear the weather. The crown of this over-sall being about 11 inches lower than the proposed weir at Torksey, will therefore be the gauge height of the Fossayke navigation, whenever the stood waters do not raise the whole country above that level; and whenever that is the case, it will be proper to open the gates of the new proposed lock joining Brayford Meer, to let the flood waters of the Till have a free vend, so as not to be unnecessarily accumulated upon these lands, that necessarily drain into the Fossayke.

I come now to prove lastly, that the whole of those lands, that necessarily drain into Fossily, will be benefited by the alterations proposed; because, as those all lay westward of Saxelby, the discharge by the weir at Torksey will have the greatest and quickest effect upon them in running off their top waters the most speedily; and respecting their ultimate drainage, it is manifest, that whenever the waters of the whole country is above the proposed gauge height of Fossilyke, that it will be the same thing to them, whether the over-sall at Brayford is in being or not; if, therefore, when at or under that height, all these lands have all the ultimate drainage they have now, or can have, they can be no losers in that article.

The only drain into Fossayke, that has the appearance of being in the least likely to be affected by the proposed advancement of the surface of the Fossayke, is Thorney Drain; I mean that with a pair of doors at Drinsey Nook. Of the circumstances of this drain I took particular notice, and must infer, that in point of ultimate drainage it fully does its business; because if it did not, as I found the water of Fossayke just covering the threshold, and a rise of the pavement or floor, from the threshold of the door towards the land, of between 9 and 10 inches, I conclude, if this drain did not, in its present circumstances, do its duty, this rise in the pavement, which operates as a dam, being taken away, and the bottom of the drain lowered correspondent thereto, it would be enabled to have run off the water lower by all this difference. I took a very careful level between the surface of the water of Fossayke as it then was, and the top of this stone pavement, and sound that the rise was  $9\frac{1}{4}$  inches in the compass of 3 yards. The water being then 4 inches below the Aisler course at Mr. Ellison's whars, if raised inches above it, this would make 9 inches; that is, the surface of Fossayke would be still a quarter of an inch below the paving, and if even with the top would

be no impediment to any water flowing over it, for water could not flow over it without having some thickness, or depth upon it; and if it was 2 inches deep, it would have an immediate fall of 2 inches into Fossake, by which it would be delivered as fully, freely, and uninterruptedly, as if it had | pit to fall into from the top of the pavement, of 100 yards deep; and in fact, as the drain's bottom (which I pursued about half a mile) feemed to lay nearly on a level with the top of the paved floor above mentioned, and was greatly trod and poached by the feet of cattle that made their passage along it, to eat the grass upon its sides, the condition of it is such, that if the Fossake, instead of being raised 9 inches above the level it then had, was raised 15 inches, I would engage, if necessary, to make it run off its water lower at half a mile distance after that, by digging it as deep as the threshold of the sluice, than it can do at its present depth and condition, though the Fossayke was totally emptied of water. It will therefore clearly appear, that the difference of an inch or two that may occasionally be made by the thickness of the sheet of water going over the over-fall at Brayford (or even if it was 6) will make no sensible difference in the effect of the operation of this drain, to which the more quick running off the top waters being the only thing desirable.

Austhorpe, December 31, 1782.

J. SMEATON.

# PROBABLE ESTIMATES of the expence of the above works.

1st. For such works of drainage as would be necessary in case the Fossayke navigation was to remain in its present state.

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- Comming out the Leffer Gottle Diames		30	0	o'
To icouring out the two	a.			
To weirs at the head of each,  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of departure of the two  To the drain leading from the subterraneous tunnel to the point of the subterraneous tunnel to the subterraneous tunnel tunne	_ 1	90	0	0
To the drain leading	2			
To the drain leading from the subterfaceous to coods, at 91. 6 d.  drains, according to Article 7th, being 400 roods, at 91. 6 d.  drains, according to Article 7th, being 400 roods, at 91. 6 d.		92	0	0
drains, according to Article 7th, being 400 roods, at 91. 02.  drains, according to Article 7th, being 400 roods, at 91. 02.  To three lengths of iron pipes, 3 feet diameter, for the grand subterraneous tunnel crossing for three lengths of iron pipes, 3 feet diameter, for the grand subterraneous tunnel crossing for the grand sub	-	10	0	0
Folldyke, Weight 5 tons 1	-	20	0	0.
To bolts, jointing and layings	_	25	0	0
To brickwork at the two ends,				
To taking off the water and pumping.  Carried or	ier L.	94z	0	<u> </u>

	_		
	L.	$J_{\bullet}$	1.
Brought over	942	0	0
To continuing the drain from the faid point of departure in Skellingthorpe, through the iron			
tunnel to Bishop's Bridge, being 332 rods, at 8s	133	0	0
To rebuilding Bishop's Bridge,	10	Ģ	0
To continuing the drain from the said point into Skellingthorpe, upon a 9 feet hottom, to the			
point K, being 410 rods, at 8s.	164	0	0
To continuing the said drain from the point K to the west boundary of Skellingthorpe, 333			
rods, at 61	100	0	0
£.	1349	0	0
To 10 per cent. contingencies upon the above articles.	135	0	0
£	. 1484	0	0

N. B. As I suppose the trustees of the Boston navigation must be considered as aggressors, the removal of the lock and staunch should be at their expence.

ESTIMATE of such works as will be necessary for the improvement of the Fossayke navigation upon the plan proposed.

To building a new lock between Fossdyke and Brayford Meer, digging and	L.	3+	d.		
pumping	500	0	0		
To additional work at the Witham tunnel, to make it serve as an aqueduct					
bridge over the drain, and to receive a gate for regulating the water,	120	0	a		
To cutting the aqueduct from the said tunnel to the Fossayke, for carrying					
the water for navigation, being 240 rods, and securely banking the same,					
at 123	144	0	0		
To two communication bridges over the same, if of brick, 20% each,	40	0	0		
To making an over-fall from Fossdyke into Brayford Meer of brick or stone,	100	0	0		
To making a staunch at Brayford Head,	150	0	0		
To deepening and scouring from Brayford Meer to Lincoln High Bridge,	25	0	0		
			10/9	0	0

The following works I look upon as contingent upon the rife of the water in Fossayke.

To carrying forward a drain for the well the corner of Saxelby Pasture, and by a							
Haddow Meadows, length 256 rods,	at 5 s.	-	•	-	64	0	0
The leaden pipe 12 cwt. at 11. 11.	-	-	-	-	13	0	0
			Carried o	over L.	77	0	0

1	0/	1							
	1	•	ght over	L.)	8+	d,			
		Broug	ght over	77	٥	Q			
To folder, labour, laying, and fixing, -	-	-	-	5	0	0			
To brickwork at each end, with proper grates to	shut and	hinder it	from						
choaking and running at improper times,	_		-	10	0	0			
To banking upon the Till up to its division, length	88 rods	on each fid	le, at						
21.6d. per rud,	-	-	-	22	0	0			
To a tunnel across the Till, wood and laying,	-	-	~	2	0	0			
							116	0	0
						L.	1195	0	0
To 10 per cent. contingencies up	on the a	bove artic	les,	-			120	0	0
						L.	1315	0	0
							-		

The making the weir at Torksey, being advantageous not only to all the lands in question, but to the navigation, by more readily freeing the same from extreams of water, and also by quieting the apprehensions that the land-owners might entertain from the rise of the surface of Fossake in dry seasons, it seems to me should be done at a joint expence.

To making the weir, walling, paving, water, imbanking between the faid cha	, and fecuring the	channel for car ain, making the	rrying off t	he gh			
the road, and pointing doors towards	the Trent, cannot l	ay at less than	-	-	500	0	0
Contingencies upon it	at 10 per cent.		-	-	50	0	0
				L.	550	0	0
	ABSTR	ACT.			_		d.
					1484	0	0
General drainage scheme.			-	_	1315	0	0
Fossey Weir and accompanyments,			-	•	550	0	0
10/A)ty went to a second to a			Total	£.	3349	0	0
Austhorpe, December 31, 17	82.			J.	SMEA	TON	1-

HOLDERNESS

## HOLDERNESS LEVELS.

REPORT of JOHN SMEATON, annexed to a Report and Estimate of Mr. GRUNDY's, concerning the Drainage of Holderness Levels.

HAVING carefully perused the foregoing observations, and also compared them with my own taken upon the place in the month of November last, and finding no difference between them that can any ways affect the practicability of the proposed drainage, or the general scheme to be made use of for that purpose; and having also considered the causes assigned by Mr. GRUND's for the drowning of this level, and the expedients to be made use for the remedy of the same, I entirely concur with him in every essential point. But as a number of adverse accidents have prevented us from meeting upon this buliness, according to the desire of the proprietors, which has prevented our comparing our ideas together; and as mens ideas often vary in particulars though they agree in general and material points; and as I find that some things have struck me in somewhat a different light to what they have done Mr. GRUNDY, I think it my duty to point out the same, not so much by way of correction of what he has proposed, as by way of supplement.

1st. In regard to the out-fall clough, Marfleet must strike every one, at first sight, being the most eligible place; and, was there any want of fall, would certainly be so; but as there appears an ample sufficiency of fall into the river Ilull at the Sugar-House clough, it's being so much above low water in the river Humber, allows it to run so much the longer; and if laid nearer low water mark (without which it could have no preserence upon the Humber) it would be more difficult to maintain a channel from the clough to low water mark; and the shore being slat and muddy, and the water ebbing out a great way, the sea-doors would be more liable to be silted up in dry seasons. I can therefore hardly tell how to give the preserence to Marsleet.

2dly. Was the eastern main drain, instead of going round by Gold Dyke Stock, to be conducted from Old Williams at b, through Fordyke, to about the midway between Fordyke Pridge and Fossam Style; and there making an obtuse angle, to meet the eastern drain, about the point VI, and then to proceed together in a right line to D, the course of the main drain would be shortened near upon a mile, which, according to the laws of drainage, is eligible, in case other circumstances of greater weight do not counteract; and then the course of the drainage of Sutton Carr, &c, which would be north, would be more natural; for, according to my information, those carrs are deeper about the fillings

fillings, and Cheffer Hole, than near Gold Dyke Stock. The lands on the fouth of Gold Dyke Stock could drain as at prefent.

3dly. In case any objection is raised by the proprietor of Waghen, now under drainage by engines (which if this scheme takes place will be unnecessary) the eastern drain may be brought from the angle between K and L, in Weel Carr, through the main drain, under Mieux Bridge; and turning S. E. near Lamber Coat Bridge, to fall into the eastern drain, in a proper direction, between b and c; and though this course would be near two miles longer than the eastern one already marked out, and therefore less eligible, yet as there is fall enough, I propose it as a practicable scheme in case of difficulties.

4thly. I apprehend a sluice of less dimensions than 24 feet water-way, would drain these levels, when the banks against the river Hull are made tight and firm; as it seems to me that country clew would be almost sussicient, was it placed where there was a proper fall: however, I would advise nothing less than two tuns of 18 or 20 feet, but dimensions, in this case, if an error, is one on the right side.

5thly. The places of the present cloughs are very proper for tunnels for taking in water from the river in dry seasons; but, as I cannot suppose, after the above works are executed, that they will ever run, I cannot think them worth maintaining in their present form. The present extraordinary inundation, I suppose, to be principally owing to the badness of the banks against the river Hull, which allow a considerable part of it's contents to be discharged upon this level.

6thly. In regard to the estimates, the shortness of the time that accidents have allowed me for these remarks, puts it out of my power to enter into them particularly; but well knowing Mr. GRUNDY's correctness and assiduity in those matters, I have only to observe, that, though I think he has allowed a sufficiency of dimensions, I should be glad he would reconsider whether the price allowed for the spade-work will be sufficient also. On this account, I would count the sum of £ 10652, exclusive of the articles of surveying, planning, schemes, estimates, supervising and other contingencies, and procuring the act.

Austhorpe, 12th January, 1764.

J. SMEATON.

EXAMINATION of Mr. GRUNDY's plan for a sea suice for the drainage of Holderness Levels, by John Smeaton.

THE general design and idea of this sluice I much approve; but as I think it may be made stronger with the same expence, I therefore submit the following remarks to Mr. GRUNDY's consideration.

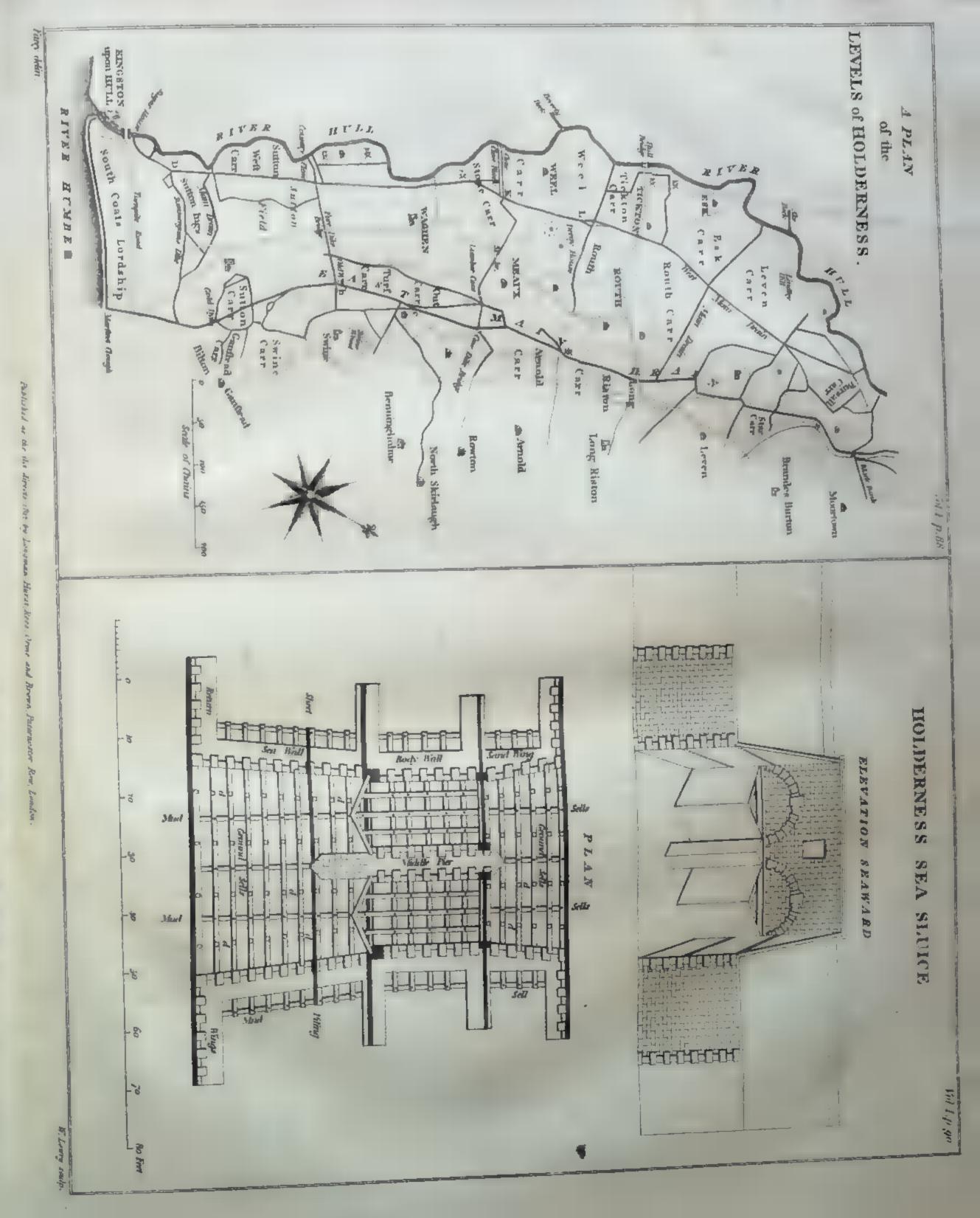
th. The sluice pit is directed to be dug 3 feet below low water mark, and the floor to be laid 1 foot below ditto.

		T. C.	In.
Thickness of the mud sells	-	1	0
The ground sells being let down thereon, I suppose 2 inches, will	rile	0	10
Thickness of the plank	-	0	3
The pointings being let into the floor, I suppose I inch, rises -	-	1	I
Total rise above mud sells pile heads,	-	3	2

Quere, Does Mr. GRUNDY propose letting the mud sells into the bottom 14 inches? if so, it should be more clearly expressed; as I suppose it is the second stoor, or top of the threshold, that is to be 1 foot under low water.

2dly. It is proposed to pile the mud sells at every 6 feet, so that every other ground sell will bear hollow upon the mud sell, which I suppose is intended for it's principal bearing; and every ground sell, being piled in the intermediate spaces, will have fuperior bearing to that where the walls stand; I would, therefore, propose to pile the mud sells under the intersection of every ground sell, and omit the intermediate piles, or do them only with slabs spiked against the ground sells, after laid; but this, in my opinion, is unnecessary; but I would add piles under every ground sell answerable to the saces of the pier, for the length of the part that at present bears hollow, and on one row of piles, at 6 feet distances only; this middle row under the pier, for the arches length, I would still continue at 6 feet distances. In this way, mud sells of 12 × 6 will do as well as 12 × 12, and the timber saved may, if thought necessary, be employed in slab piling the intermediate spaces.

3dly. The projection of the floor beyond the walls, I think not only an useless expence, but prejudicial in effect, because the back side of the wall bears hollow, and not immediately upon the pile heads; 'tis true, a wall of this sort is not inclined to



fall backwards, but if the ground should prove bad, and the wall be inclined to fettle, (for which cause only piles seem necessary behind the front) they had better be applied directly underneath; and if the two outfide mud fells, answerable to the back of the walls, are piled at 6 feet distances only, I think it sufficient.

4thly. The row of dovetailed piles under the points of the projection of the pier, I think may be safely omitted, unless the ground is very bad indeed.

5thly. If 9 inch spikes are intended for the 5 inch plank piling, they will reach only 4 inches into the wood; I have, therefore, supposed them, in the estimate, to be of 11 inches.

6thly. Out of the timber supposed to be faved as above, I would lay an additional ground sell close to the other, directly under the points of the pointings, that the jagged bolts may there have something else besides the plank to hang by; but to discontinue them upon the mud sells in the face of the walls: the three ground sells and plank piles to be all bolted together. This last ground sell I would support by 4 piles, correspondent to those marked dddd.

7thly. I think I foot rise at the threshold very sufficient, and the second stoor plank may be of two inches, or the second beams of 12 × 9. The 20 inch bolts proposed for the 14 inch pointings, leaves but 6 inches to go into the wood below, of which 2 inches is plank; they should be two feet at least.

8thly. It would confiderably strengthen the pointings to put a brace or stretcher of an equal height with themselves, cross the pier, according to the direction of the dovetail piles; so that the string pieces, these braces, and the head of the threshold, would all mitre together; and in like manner to fix on a piece jump against the outside heels, to reach about 6 feet into the wall, and to be bolted on with two jagged bolts, each the same as the pointings are fixed by, for which there is provision in the estimate.

9thly. If the lime rubble is mixed with a little quick lime it will swell and become quite compact, which method I have used in fillings; and the second soor I think had better be filled with folid brickwork.

10thly. The projecting pier I think had better be no longer than sufficient to fasten the studs, as the water will thereby more readily act behind, and shut the doors.

11th. In regard to the plan of the walls, I think a 5 feet base, the length of the arches in this light, unnecessary; that as the arches will ever prevent the external pressure of the earth from driving them inwards, a wall of 4 feet base and 3 feet at the springers will be sufficient; but considered as an abutment to the arches, independent of the weight of earth to be rammed behind, I think it insufficient for a height of 12 feet; in this light the base had better be 7 feet, and 3 feet at top; the contre forts will undoubtedly support the extremities of the arches, but a 15 feet hollow bearing, where there is any dependence, I think is too great in brickwork or masonry.

12th. A base of  $4\frac{1}{2}$  feet for the wing walls, is certainly too little for a wall that is to rise at a mean 22 feet, without the help of land ties, or cross beams; and, as I am very averse to those expedients, I would propose to make the base of the wings, at the set-on to the body, 9 feet thick; 6 feet thick joining the returns, and 6 feet for the returns; and to make regular sets-off on the back side, so as to be every where 2 feet at top; this will reduce the walls to full as small a size as is supposed at the height of 12 feet; so that the only addition will be 1 foot 6 inches mean thickness upon 12 feet high in the wings, and 1 foot thickness to ditto height in the returns, which, with the contre forts in the wings and returns, will make about  $7\frac{1}{2}$  rods of brickwork; which at 61. per rod comes to 451. to do it durable and lasting, whereas with land ties and beams it comes to 571. 85. No addition of expence in the floor will be required, or alteration, save that I would conform it to this figure; and it will be necessary to lay in, instead of common planking, ribbands or whole pieces of 6 inches thick, in the sace of the wing walls, to hinder their sliding upon the floor.

13th. As the upper pointing is difficult to be supported, from the pressure of the water downwards, I have proposed in the estimate to suspend them, by iron loops and stays, to the key-stones of the arches, and plank them flat upon the top.

14th. I apprehend Mr. GRUNDY has, in the height of his doors, had a view to the passages being navigable; otherwise I think, if the doors were only 8 or 9 seet high, (which would be fully sufficient for the discharge of the waters) they would be lighter, and therefore move more readily as well as be in effect stronger.

Austhorpe, 13th December, 1764.

J. SMEATON.

8cc.

P. S. It seems to me that there is not occasion to dig the sluice pit to so great a general width as 65 seet: was I to execute it I should not open the ground to take in more than the extremity of the walls at bottom, and notch in the abutments, returns,

&c. in which case the main pit will not be above 50 feet bottom. I have also altered the position of the sluice pit in the general plan, in order to give it a better direction into the river, which, being in dotted lines, will readily be distinguished.

N. B. I have in the estimate supposed the walls to be carried up 12 feet high, the same thickness as ordered for the base.

ESTIMATE of Mr. GRUNDY's plan for a sea sluice for the drainage of Holderness

Levels.

#### CARPENTRY.

In 84 piles under the mud fells, being 10 inches by 12 head, and 10 feet long, 1 piece of 1	2 inches	Cabe Ft.
fquare and 10 feet long, make 2 piles; therefore the folid contents,	-	420
In 7 mud sells, 64 feet long, 12 by 12,	-	448
In 96 bearing piles, 10 by 12 head, and 10 feet long,	-	480
	Cube Ft.	
1 Grounding to sea sheet piling, 73 seet long, 12 × 12,	73	
9 Ditto u tae sea apron mean length 49 feet, 12 × 12,	441	
2 Ditto under the sea doors, 62 feet long,	124	
5 Ditto under the body of the fluice. 44 feet long	220	
2 Ditto under the land doors, 57 feet long,	114	
4 Ditto under the land apron, 45 feet long,	180	
Ditto to land theet piling, 62 feet long,	62	
In 24 ground ways, 12 × 12,		1214
In 2 rows of 12 feet dovetail piles under extremity of the sea aprons and sea doors, length		
134 feet, there is feet superficial,	1608	
In 2 rows of 10 feet ditta, length 106 feet, feet superficial,	1060	
Ill 2 10/45 Of 10 rect mited, length 100 rect, something and state of the state of		
Consecuted Case of degree in the	2568	
Superficial feet of dovetail piles,	334	
Allow for tongucing		
	3002	L
Superficial feet, 5 inches thick,		
cubic feet,	1251	
The folia contents energy 15.	-	
1 Row of ditto in the extremity of the land apron, 4 inches thick, and being in length 62 feet, and allowing † for tongueing, make, in folid contents,	.207	
		1458
Timber in the 5 rows of dovetail piling,		1420
3640 Feet superficial of plank in the steor, being 3 inches thick, contains solid,		
		6 Ground

	Cube Ft.		
6 Ground fells for the second floors under the arches, mean length 21 feet, 12 × 10,			
folid contents,	106		
4 String pieces, 20 feet long, PO X 6	36		
4 Pointings, 14 × 16, and 7 feet long each,	44		
2. Land thresholds, 14 × 16, and 15½ feet long,	49		
Plank for the second floor, 3 inches thick, 504 feet superficial, containing solid	126		
Timber in the second floor and thresholds,		3	61
Riga timber in the floor, -	Cube fee	t 52	gr
	£.	5.	d.
	_ 308	12	10
To Riga timber in the floor, 5291 feet solid, at 14d.  Allow for waste in converting to the proper scantlings one eighth	- 38	11	7
	- 347	4.	c
To timber in the floor,	- 22	0	0
To preparing and driving 180 piles of 10 feet long, at 25. 6 d. each pile,	- 27	15	0
To framing, fawing and laying the floor, containing 37 square, at 15%.	- 44	9	4
To 2668 feet superficial of dovetail piling, sawing, making and driving, at 4 d.  To laying 37 square of planking in the floor, including sawing and caulking, at 71. 6 d.			
To laying 37 Iquare of planking in the noor, including lawing and laying the second floor, containing $5\frac{1}{2}$ square, at 11. 21. 6d.	- 6	3	1
	- 114	5	7
Workmanship in the floor,  Timber in ditto,	- 347	4	5
Carpentry in the floor,	£. 461	10	0
Masons and Bricklayers work.			
The external circumference of the walls and pier is 292 feet by 12 feet high, produc	23		
aroa feet of face work, which will be, at a medium, 1 foot 3 inches thick of Itons	e;		
this produces 4380 cube feet, which, delivered at 1s. 6d. per foot, comes to,	- 328		0
The fetting and making mortar for ditto, at 1 d. per foot,	- 18	5	0
This being supposed to be set 6 inches breadth in tarras mortar, and the hollow pos	its		
wholly bedded therein, will take 50 bushels of tarras, at 3s 6d.	- 8	-	0
To extra labour in beating the mortar made therewith, at 11. 6d. per bushel,		15	0
To lime and fand for making the tarras mortar, and bedding the stone work, containing	ng - 6	6	0
14 rods, = 9s			
Masonry to 12 feet high,	- £. 365	11	0
	The second second		

To stone facings for the wings and returns to 6 feet above the	Sup. Ft.	Solid Ft.			
foring of the arches,	966	1208			
To ditto in the 2 face walls,	1088	1360			
To ditto in the 4 rampart walls,	460	565			
	2514	3133			
	-		_		
				5. 4	4.
To 3133 cube feet of stone work, M 11. 8d. per foot, -	-	-	234	19 (	6
To fetting ditto and making mortar, I Id. per foot,	-		13	1	I
To lime and fand for mortar for ditto, 10 rods, at 9s. per rod,	-	-	4	10	•
Masonry above 12 feet high,	-		252	10	7
The state of the s			365		0
Masonry below 12 feet high,		-	303	**	-
Masonry in the face of the walls,	_	1	Ç. 618	1	7
				_	-
Estimation of a rod of B	rickwork.				
			L.	S.	d.
To 4500 bricks, at 151. per thousand,	-		3	7	6
To 20 bushels of Houghton lime, at 8 d		-	0	13	4
To 40 bushels of clean sand, at 3 d	-		0	10	0
To workmanship,	-		I		0
10 Workmannip,					
Rod of brickwork,	-	~ -	5	1-8	10
			-	-	_
This, in the following estimate, I call -			6	a	0
The whole contents in solid, to 12 feet high, is 13548 cube fee	t, from which	h deducting			
4380, the cube measure of the masonry, there remains 9168	cube feet of	brickwork,			
making 29,7 rods, at 6%	-		17.8	- 34	.0
The brick backing for the wings, and returns, to make the whole	e 3 feet				
thick at a medium,	16	go cube feet.			
To ditto for the faces to make the same thickness,	- 143				
To ditto in the rampart walls, to make the whole, at a medium,	■ feet				
	- 4:	20			
3 inches thick,		12			
To cube measure in the arches a brick and half					
Distance la considerada	- 42	o cube feet.			
Brickwork compleated,  The upper works in brick contain 4250 cube feet, which, at					
The upper works in brick contain 4250 cube reet, which	+ -		-8:	2 46	0
inches thick, contains 13,8 rods, at 61.		;	Antinipe (		
m t.1. t. d. hashing and ambee	-		£. 26	51 10	9
Brickwork in the backing and arches,					

## Carpentry in the sea and land doors and pointings.

Carpentry in the lea and land doors and pointings.				
A sea door, Ft. in cube				
In 1 turning post, 13 feet long, 9 × 9, 7 4				
1 Clapping post, 12 feet long, 9 × 9, 6 3				
The under rail and upper ditto, 9-x 9, 7 11				
4 Rails, 28 feet long, 9 × 7 ½, 13 3				
66 Feet of inch and ½ plank 8 3				
Solid timber in each door, 43 °				
To 43 feet of timber in each door, framing and hanging, at 3 s. 6 d. per foot,	is	L.	S.	<i>đ</i> .
71. 10s. 6d. each door, and for 4 sea doors, Cube Fi	•	30	2	0
In the main beam for the pointings, 34 feet long, 12 × 14;				
The 4 pointings, 28 feet long, 12 × 12,				
The king pieces, 6 feet long, 12 × 12, 6				
The covering with 3 inch plank 36 feet superficial,				
To timber and training in the pointings, at 3 st one		14	10	6
Land doors, being 11 1/2 feet wide by 8 feet high, contain 92 feet superficial, and				
being 4 inches thick, 31				
With 4 battens on each side, 2 inches thick, 1 foot broad, and 8 feet long,				
contain 64 feet superficial, 11				
Solid timber in each land door, Feet 42				
To 42 cube feet of timber in each land door, framing and putting in place, at 35. 6d.				
is 71. 7s. each, and for 2 doors,		14	14	0
Carpentry in the doors and pointings,	L.	59	6	6
Carpentry in the beams and land tyes.  Cube F				
To 4 land tyes in each sea wing, and 2 in each return, sea and land in all 16,				
to be 24 feet long, 10 × 6, 171				
To 16 cross pieces and ditto string pieces, 3 feet long, 10 × 6, 43				
		32	2	0
To cube feet in land tyes, at 3s.  To 32 10 feet piles, 10 × 8 head; timber, making and driving, at 6s. each,		.9	12	0
To 3 beams of Riga fir over the sea, and 1 over the land apron, mean length 33 feet,				
12 × 12; 132 feet, at 14 d.		7	14	0
To 16 knee pieces for the same, at 51.		4	0	0
To making, getting into place, and fixing the beams,		4	0	0
Carpentry in the beams and land tyes,		57	8	0
Ditto in the doors and pointings,		59	6	6
Carpentry in the upper works,	£.	116	14	6
	-			

Iron

## Iron Work.

TIOIL TTOIR.	1	bs.				
Tail sheeting 73 feet, 146 of 11 inch spikes,		46				
		•				
Row in point of pier 47 feet, 94 of 10 inch ditto,		73				
Ditto in extremity of land apron 63 feet, 126 of 9 inch ditto,		72	£		ı,	d.
en out of the floor of the floor of the floor		291 lbs.			4	
To spikes for the sheet piling at $3\frac{1}{2}d$ .		-	7		T	2
To 16 bolts for bolting the ground fells and sheet piles, together in the 2	. 10.9.3 mm	act the				
fea and land doors, weighing 4 \frac{1}{4} lbs. each, in all 76 lbs. at 6d	_	-		1		0
To 2500 8 inch spikes for the floor, weight to Cwt. at 11. 101. per Cv	VI.	-				0
To 28 jagged bolts, 2 feet long and 1 inch thick, weight to lbs. containing	ng 2801ba	. at 4 <i>d</i> .	4	Ļ 1	13	4
To spikes for the second sloor, 1 Cwt. at 1 h. 10s	-	-		I	10	0
			2	7	6	2 <u>I</u>
				2	13	9 1/2
Contingencies thereon,			_		-3	73
Iron Work in the floor,		-	L. 3	0	0	0
To 4 pair of L's and 8 ditto of L's for each sea door, and for the 4 doors	s 48 pair,	weigh-				
ing, with their rivets, 14lb. per pair, in the whole 6 Cwt. at 21. 24.		-	- 1	2	12	0
To ½ crown nails for the planking of the gates ½ Cwt.		-		٥	10	9
10 2 Crown naits for the planting of the guite		lbs.				
- 1 Conscionances weight to be each.	_	40				
To 4 9-inch hoops for the feet of turning posts, weight to lbs. each,	_	36				
To 4 8-inch hoops for top: of ditto, 9 lbs. each,		80				
To + 2-inch gudgeon: for top of ditto, 20 lbs. each,		0.0				
10 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		112				
To 4 loops or staples for fixing ditto, 28 lbs. each,	-	112				
To 4 loops or staples for fixing ditto, 28 lbs. each,	-	268 at	$4\frac{1}{2}d$ .	5	•	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,			4½d.	5	•	6
To 4 loops or staples for fixing ditto, 28 lbs. each,	- Cwt	268 at	4 ½ d.	5	•	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,	- Cwt	268 at	4 ½ d.	5	•	6
To 4 loops or staples for fixing ditto, 28 lbs, each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,	- Cwt	268 at	4 ½ d.	5	0	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 serew bolts, 18 inches long, 4 thick, weight	Cwt	268 at 1bs.	4 ½ d.	5	0	6
To 4 loops or staples for fixing ditto, 28 lbs, each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,	Cwt	268 at 1bs. 0 16 28	4 ½ d.	5	0	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 screw bolts, 18 inches long, \(\frac{1}{4}\) thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.	Cwt	268 at 1bs. 0	4 ½ d.	5	0	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 screw bolts, 18 inches long, 4 thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.  To bolts for the upper pointings, at 6 d. per lb.	- 1 	268 at  1bs.  0 16 28 44		5	0	6
To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 screw bolts, 18 inches long, 4 thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.  To bolts for the upper pointings, at 6 d. per lb.	- 1 	268 at  1bs.  0 16 28 44		5	2	6
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To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 serew bolts, 18 inches long, \(\frac{1}{2}\) thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.  To bolts for the upper pointings, at 6 d. per lb.  To 2 sets of loops and stays for hooking the upper points of the key 50 lbs. each, at 4\(\frac{1}{2}\)d.	y-stone of	268 at  1bs.  0 16 28 44		1 1 0 2	17 5	•
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To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 serew bolts, 18 inches long, \(\frac{1}{2}\) thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.  To bolts for the upper pointings, at 6 d. per lb.  To 2 sets of loops and stays for hooking the upper points of the key 50 lbs. each, at 4\(\frac{1}{2}\)d.	y-ftone of	268 at  1bs.  0 16 28 44		1 1 9 2	17 5	•
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To 4 loops or staples for fixing ditto, 28 lbs. each,  To hoops, loops and gudgeons, for sea gates,  To 4 bottom gudgeons and 4 pots of cast iron,  To 4 serew bolts, 18 inches long, \(\frac{1}{2}\) thick, weight  To 4 ditto of 4 feet long for ditto, weight 7 lbs.  To bolts for the upper pointings, at 6 d. per lb.  To 2 sets of loops and stays for hooking the upper points of the key 50 lbs. each, at \(\frac{1}{2}\)d.  To spikes for the planking of the upper pointings,  To rivet nails for the land doors, 100 in each door, \(\frac{1}{2}\) inch thick, at \(\frac{1}{2}\)d.  For drawing the land door  To 2 slass and eyes with rivets,  To 2 studs with plates for sustening to the wall, 12 lbs. each,	y-ftone of	268 at 1bs. 0 16 28 44 the arch, 64		1 1 9 2	17 5	•
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L 98 1				
		£.	s.	d.
Brought over,		29	Io	q
To a common hand-screw sitted up for drawing the gates,	•	5	0	ó
To 50 cramps for the cappings, 2 lbs. each, 100 lbs. at 4d.	~	I	z 3.	4
To 5 pigs of lead to fasten cramps and iron work, at 16s. each, -	-	4	0	0
				-
		40	4	1
Contingencies,	4+	4	15	11
				-
Iron work in the upper works,	-	45	o	0
Ditto in the floor,	-	30	0	0
			-	
Iron work in the whole,	- £.	75	0	0
To 188 cube yards of lime-stone rubbish, mixed with t bushel per yard of quick lim	e,.			
well blended together, and rammed in between the timbers of the floor before it				
planked,	-	28	4	0
To ½ a rod of brickwork between the timbers of the second floor, close laid in and fille	ed			
with mortar,	2	3	0	0
Filling in the floor, = 5 5 5		31	4	0
		-		
ABSTRACT.				
		L.	F.	ď.
Carpentry in the floor,		461	10	0
Masonry in the face of the walls;		618	1	7
Brickwork in the backing and arches,		261	IO	0
Carpentry in the upper works,		116	14	6
Iron works in the whole,		75	0	0

Fillings in the floor,

Drainage of the water, supervisal, and contingencies,

#### BRISTOL BRIDGE,

QUESTIONS proposed by Mr. Stratford, Engineer, concerning Bristol Bridge; answered by Mr. Smeaton.

Quere 1st. FROM the state of the old pillars, and strata below the bed of the river, to the solid red sand rock, will it be prudent, or adviseable, to attempt the construction of a new superstructure on such old precarious soundations?

Having duly considered the several matters stated in the foregoing discourse\*, as well as the several plans, elevations, and sections, I am of opinion as follows:

Answer 1st. As all the old pillars appear to be ill built and damaged, and not sufficiently deep below the bed of the river, which will always render them subject to further injuries from the action of the water, which appears here to be very considerable, I should think this sufficient to their condemnation, if the circumstances of their being ill sized, ill shaped, and ill placed, were not in the present case to be added.

Quere 2d. From the forementioned account of the freshes, will not any attempt to bar up the bed of the river under the bridge be extremely injudicious, and a measure that will greatly add to the present inconveniencies selt at the head of the back?

Answer. The bars mentioned to be thrown up, both above and below bridge, have undoubtedly been formed by the matter removed by the current from between the piers; which removal has been occasioned by the bulk of the pillars too much straightening the water-way, which, increasing the current there, has taken out the matter and increased the depth, thereby nature having in some measure relieved herself, by getting in depth what she was debarred from in width; an attempt therefore to refill those cain depth what she was debarred from in width; an attempt therefore to refill those cavities will either be attended with the same consequences, and an increase of the bars, vities will either be added, is so heavy and compact as to resist the current, the current must be proportionably encreased thereby. I should therefore think this expedient in this place very unadviseable.

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Meaning Mr. Stratford's description of the situation, condition, &c. of the old pillars, and of the several strata under the bed of the river, &c.

Quere 3d. The position of the bridge being a matter of moment in bridge building, will not the changing the present position of the old bridge be a real improvement to the part of Bristol at the head of the back, as it will facilitate the passage of all sorts of vessels through bridge; and may not a reasonable expence to gain that advantage be money judiciously expended for the benefit of the city of Bristol?

Answer. All bridges ought as near as possible to have their piers parallel to the natural current of the water, in the place where they stand; yet a small deviation therefrom, so far as it respects the passage of the water only, is not of great consequence to a work that is otherwise firm and well founded: but in the present case, with respect to the laying and passage of vessels, the deviation very unluckily happens to be the wrong way, and therefore in the reconstructing this bridge ought to be rectified. I don't mean that the piers ought to be out of parallel with the stream, but if they had happened to have deviated as much the contrary way, there probably would have been no need of a change. This ought however to be attended to, that at the same time the freshes, sloods, and strong ebbs, render the vessels along side the quay less steady, it may be the means of preserving the sace of the quays from an addition of silt or mud; yet the quantity of alteration proposed, cannot I think be attended with any danger from this quarter.

"Question 4th. In case of a three-arched bridge, situated on so rapid a river as at Bristol "Bridge, will it not be more eligible to construct the salient angles or becs of the piers "with cylindric surfaces of 60 degrees, rather than an angle of 90 degrees, or rectangular?"

Answer. As the shoulder angles of the piers obstructed the water's passage, and the more so as these angles are less obtuse, in all currents they ought to be rounded off; provided this is done, it is little material what angle is formed at the bec; but no way is more advantageous than cylindric surfaces of 60 degrees, which is at present the practice of most foreign engineers.

"Question 5th. The first design a single arched bridge, the cord at low water mark

150 feet, the plumb or perpendicular  $32\frac{1}{2}$  feet, the springers of the arch to be carried

down, and sunk into the solid red sand rock, according to the plan referred to;

will there be any fort of danger or hazard in executing a work of this large span, under

a supposition that the springers of the arches are carried down to the solid rock?"

"N. B. The stone designed for the bridge is a sand stone, which rises soft in the quarry, but immediately hardens in the open air to an amazing sirm texture, at the same time the stone can be raised in blocks of any size: I propose one fort of arch stones of  $6\frac{1}{3}$  seet long, and 3 feet in the suffit or thickness, and from 3 to 4 wide; the second set 4 feet 3 inches long, 4 or 5 feet wide, and of the former thickness; the counter arch to bond in with the principal arch, according to the section referred to. The stone designed for the counter arch is excellent, being 4, 5, or 6 inches thick, very wide and long.

The lime for the mortar of the bridge is of an admirable nature; one fort will set and cement under water, equal with Dutch terras; and the other will also set and cement the stonework together, as if formed of one solid mass.

This arch from the springers contains 125 degrees of a circle, consequently is 5 degrees above of a semicircle, which Palladio recommends in all his bridges.

As this arch is to be sounded upon the solid rock, this arch may be looked upon as semicircular, the rock may evidently be supposed the part of the arch desicient of a semicircle. A great advantage in a scheme arch, built on a solid rock, is, that the less number of degrees the arch contains, the stronger the arch will be."

Answer. I look upon it that no limit to the span of arches, in proportion to their rise, has as yet been found, since the widest and statest arches that have been attempted, upon right principles, have succeeded as well as the narrowest and highest, provided the abutments are good, and the stone and cement whereof they are composed are of a firm texture, as in the present case they are said to be: and as no abutment can be better than a solid rock, and since the manner of carrying down the arch, and stepping it thereupon according to the section, is quite proper, I see no reason to doubt of success, if built upon the plan now before me.

The Aberthan or Watchet lime, which I suppose is here hinted at, I look upon, from experience, to be the best in the world for works under water.

Question 6th. The second design I propose to consist of a large central arch, and two side arches. In this design will it not be most adviseable to carry down the piers and abutments to the solid rock.

Answer. Though I apprehend the piers of a bridge might be lecurely fixed upon any of the strata mentioned, by pileing and other timber-work, provided there was no other

other to come at, yet as a rock is undeniable, I look upon it worthy of a confiderable addition of expence to come at it in a work intended to be lasting: how far it may be practicable in the strata mentioned to get down to the rock by battardeaux, in the middle of the river, I am somewhat dubious; and though it may be come at by the caissoon method, yet, as I think to interpose a grating or sloor of timber between the solid rock and solid masonry, is not quite the thing to be wished for; I should therefore prefer the single arch, as having sewer soundations, and those more easy to be senced off and come at, and should prefer the 150 seet arch to one of lesser span, as the abutments will advance less into the river.

Question 7th. The third design, proposed by Mr. BRIDGES, where the new piers are to be seated on a coping on the old pillars. But as there are so many real objections to this plan, will it not be the most judicious and adviseable step entirely to reject every proposal already offered or to be offered for executing that vague scheme.

Answer. As to Mr. Bridges's plan I can say nothing, as not having seen it; but if the old piers are as represented, I think it quite wrong to make use of it at all, for the reasons in the first answer. This I am sure of, if the bottom is unsound, no coping, or any thing else that can be done, can make them sound. Besides, to leave the old spreading bottoms to project under water much beyond the new shafts, and that in an irregular manner, would be very prejudicial, not only to the passage of the water, but the navigation; I therefore must conclude, that if a new superstructure must need be built upon the old bottom, I think it most adviseable to shape the piers, and build the bridge conformable.

The queries answered by J. SMEATON.

Austborpe, November 24, 1762.

### RYE HARBOUR.

The REPORT of John Smeaton upon the harbour of Rye, in the county of Suffex.

THE harbour of Rye, once so famous and sourishing, lays in the bottom of a bay, terminated by the point of Dungeness on the east, and of Beachy Head on the west, but more immediately by Point Fairlee, which lays almost in the same line, at about the distance of 5 miles. This harbour, according to tradition, was scrmerly very large, capacious, and deep, so that many large ships might lay therein, sheltered from all winds, at anchor at low water. In this state the sea waters every tide overslowed very large tract of country (now converted into marshes), the influx and resux of which waters from and to the sea produced so great a power of cleansing and opening, as to maintain itself a channel wide and deep enough for the above beneficial purposes.

Now as the whole of the waters so slowing in and out each tide must pass through the mouth of the harbour, the action thereabouts would be the strongest of all, and in. proportion weak towards the remote extremities: the mud, therefore, and impurities brought in by the sea, and soil brought down by the rains from the high country, would first of all be lodged at those extremities, which gathering by degrees, in proportion lessen the capacity of the reservoir, which of consequence weakens the influx and efflux, and thereby increases the tendency to silt, or, as it is here called, to swerve up; and those surfaces so overslowed being by degrees raised out of the reach of common neap tides, begin to gather a surface of grass, which tempting the husbandman to enclose with banks, he thereby shuts out the sea totally, and in consequence weakens the cleanfing power more suddenly than would happen in a state of nature; so that in time the whole of such an inlet will be silted or swerved up, unless a sufficient quantity of land or flood waters have their passage through the same to sea; and the channel remaining at last will be in proportion to the quantity and rapidity of these flood waters. This is the natural tendency of every creek or harbour upon the fea, but differing greatly in degree as fituations and quantity of fresh waters from the land, and the impurity of the land or sea water, disfer in one place from another.

It appears further, that an immense quantity of slint, pebbles, or broken slints, rounded by the action of the sea, commonly called stringle or beach, and which have either

either proceeded from the chalk cliffs on the coast, or have been washed up from the bottom of the sea, are produced to the westward of this harbour, and being driven on the shore, which runs in a general direction nearly W. S. W. and E. N. E. the wind at any point between S, and S. W. causes the seas to strike the shore in an oblique direction, and not only to heap up the beach upon the coast, but to drive it along the shore to E. N. E. into the bottom of the bay; that is, into the mouth of the harbour, from whence there is no possibility of return by a contrary action, because all winds from E. to S. E. which should produce that effect, are in a great measure land-locked, and not only fo, but are generally less continued and violent than the South-Westerly. Hence then it appears, that two powers of nature are together combined to produce the destruction of this harbour, viz. the silting within, and the action of the winds and seas without, upon the shingle, to block up its mouth; nor could this last be possibly avoided, in a very little time, was it not for the action of the land waters, which will always maintain themselves a passage to sea, (while they have no other) and though considerable in the winter season, are yet very inadequate to the keeping open such an arm of the sea as this has formerly been, or even now is. The quantity of beach or shingle that has thus gathered at the bottom of this bay and mouth of the old harbour makes I furface of several hundred acres, the position of which in some measure appears by the plan hereto annexed, and is at present in an increasing state; for, as I am informed, that which at present is called the outermost west point has been formed within these ten years; and that which is now called the innermost was then called the outermost; and the point marked B in the plan was then called the innermost, which is conformable to a plan made in the year 1738. Hence it appears, that a succession of points have formed themselves to the westward of the harbour's mouth, every one leaving a more narrow passage than the former, the present opening between the present points not being above 100 yards wide. There also appears to be a body of beach, marked in the plan A, which is driving down from the westward, in all probability, and will form a point without the prefent, leaving a passage still narrower. From this view it appears, that the old harbour has been subject to great mutation, and is likely to be subject to still more, and all for the worfe; and all able artists, who have surveyed the same, have agreed, that nothing to purpose can be done towards restoring the old harbour, or maintaining the same in any tolerable state. In this condition it appeared upon a survey in 1698, by two Commissioners of the Navy and two Elder Brethren of the Trinity House, by order of the Right Hon. the Lords of the Admiralty, who conclude their Report with faying, " And therefore we take this harbour to be almost entirely lost, at least in no condition to be preserved for any purpose of the navigation." Indeed, three gentlemen, who were sent to survey the harbour of Rye, by order of the same board, in the year 1719, after declaring their fenfibility

fensibility of the former utility of this harbour, and the bad condition it was then in, propose a remedy; but as this appears quite inadequate to the object, since that time a new harbour was projected, and in part executed, by the samous Captain Punny, who, after performing several great works in Russia, and effectually stopping the breach in the river Thames at Dagenham, was employed here; and this new harbour has been carried on, with some interruption, from that time to this. Its general design and situation is as follows:

The mouth of the new harbour is fituated about two miles to the westward of the old one, where the coast makes nearly a straight line for several miles together, and though altogether formed with beach, yet feems to have had no confiderable increase of late years, at least not fince this harbour was begun; for though a succession of shingle is moving to the eastward, it does not stay here, but lodges in the bottom of the bay. The coast being hereabout W. S. W. and E. N. E. as before mentioned, the mouth of the harbour points nearly square thereto, that is, to S. S. E. or rather S. E. by S. At the foot of the beach, which is about low water mark at neap tides, begins a fine firm fand, regularly inclined towards low water, which at spring tides is about 257 yards from the foot of the beach, and from thence inclines by very regular and gradual foundings, so as to make 20 seet water at low water spring tides, and about 23 seet at ditto neap tides, at above a mile right out from the harbour's mouth, which foundings gradually increase further out, and the whole of the bay is excellent anchoring ground, as I am informed. The tides here, at a common spring tide, rise above low water mark 23 feet, and neap tides about 14, that is about 17 feet above low water mark spring tides, which are the greatest tides I have met with on this coast. The direction of the tides is nearly along shore, and being some distance (on account of the depth of the bay) from the main channel tide, are very gentle, and are attended with this particular circumstance, that whereas the main channel tide sets to the eastward for some time (in most places three hours) after high water, which occasions a strong current to the eastward, a tne time of high water; now in the bottom of this bay, the time of still water, and that of high water, are both nearly the same, which is a great advantage to ships steering into the harbour's mouth, especially in bad weather; all which circumstances, viz. the great rise of tides, the easiness of the current, and stillness at high water, when vessels chiefly go in and out, must be allowed to be advantages savourable to the construction of an harbour in this place.

With respect to the harbour itself, in its original design, it had two stone pier heads projected into the sea, as far as the foot of the beach, their distance 120 seet, which makes the opening of the harbour's mouth; but as the course of the beach was intermakes the opening of the harbour's mouth; but as the course of the beach was intercepted Vol. I.

cepted by the west head, and in consequence a body of it collected behind the said head, the west head has lately been advanced further out with timber and stone, so as to overlay the east pier 210 feet, which addition is not only the means of preventing the beach from getting round the head so easily as before, but greatly facilitates the entry of the harbour, especially in the time of heavy seas from the S. W. as I have had an opportunity of being eye-witness of a vessel coming in for shelter under these circumstances.

From the pier head the width of the harbour enlarges to about 200 feet wide, and is altogether in the form of a canal, which, in my opinion, is preferable to any other for an artificial harbour, on account of the advantages in scouring, where the whole depends thereon.

At the distance of 730 yards, or thereabouts, within the piers, is placed a large navigable stone sluice, and the whole of the canal between the pier heads and the sluice is formed into the arch of a circle of about 45 degrees; so that no part of the mouth of the harbour can be seen from the sluice, nor any part of the sluice from the mouth of the harbour; in consequence whereof, not only the destruction of the sluice-gates by the sea's rolling in upon them, are prevented, but a space of above 200 yards of the canal, from the sluice downwards, becomes still water, in time of the greatest seas, at the harbour's mouth, which is particularly convenient for fuch vessels as come in for shelter, and only wait to take the advantage of better weather, or a favourable wind. At present the bottom of the channel between the pier heads is about 6 feet above low water mark at spring tides, and about 3 feet above the cill of the sluice: so that at prefent there is 17 feet water between the heads at spring tides, and 11 feet at neap tides; but as the body of beach that served as a dam in the harbour's mouth, to prevent the fea from coming in till the works within were compleated, has never been totally removed, and as in its present state a sufficient body of back water cannot be collected for effectually cleanfing and keeping open the mouth of the harbour, it cannot be looked upon at present as having the greatest depth of water of which it is capable. I am therefore of opinion, when these requisites are provided for by compleating the whole scheme, that then the mouth of the harbour, as well as the internal part up to the fluice, may be kept clear, at least as low as the level of the cill of the gates; in which case the common spring tides will give 20 seet water into the harbour and through the sluice, and neap tides 14 feet; which latter I apprehend to be sussicient for common built merchants vessels of 300 tons burthen.

The fluice is built of Partland stone, and consists of two openings, one of 40 feet, shut by folding gates pointed to landward, the other of 30 feet clear water-way, shut by five draw-gates of 6 feet wide each: the use of these gates is to shut in the tides received into the canal above the sluice on tide of slood, into which vessels may then pass, or at high water through the great opening, or repass at high water or on tide of ebb; and gates being afterwards shut, and thereby a body of water penned into the canal above the sluice, serves either to keep vessels therein assort during the whole time of tide, or being let off at low water by means of the draw-gates, produces a scour for keeping open the harbour below.

The length of the canal above the fluice is half a mile very nearly, and at medium is about 150 feet wide at the water's furface, 70 feet at bottom, and dug down to the level of the cill of the fluice. This canal alone, exclusive of the outer harbour, will take in above 200 fail of vessels, but yet does not contain a sufficient body of water to produce the necessary scours below; and surthermore, this part of the canal being liable to filt up by the deposition of mud brought in by the sea, will in a sew years be choaked up, and rendered entirely useless; the filt being gathered at least 4 seet deep at the head of the canal since July last, when the harbour was opened; what therefore is principally wanting to compleat what I apprehend to be the original scheme, is to bring the land waters and freshes of three rivers, that now discharge themselves into the old harbour of Rye, through the new harbour, by which means the whole will be kept clear, as appears to me for the following reasons:

The river Rother, together with the Breade and Tillingham channels, which unite in the old harbour of Rye, are faid to receive the downfall and spring waters of above an hundred thousand acres of land; the discharge from whence in rainy seasons must be very considerable. But without entering into a minute disquisition concerning the quantity of surface, the most certain way of judging appears to me from observation of the size and fort of channel that those rivers respectively are enabled to maintain, so far up as where the silt, brought in by the sea on one hand, and driven out by the land waters on the other, is already come to a balance; and such I take to be the channel of the Rother immediately below Scotch Flat Sluice; the Breade or Winchelsea channel below Winchelsea Sluice; and the Tillingham channel about a mile above the New Bridge at Rye. Now it appears to me, that the Rother and Tillingham waters united are sufficient to maintain a channel, from the new canal to the town of Rye, capable of carrying up vessels of 300 tons; that the Breade channel is capable of maintaining a channel sufficient for ships of 100 tons to Winchelsea Sluice; and that the three together are capable of preserving an

open channel through the prefent canal and new harbour, so as to make at least 14 sect water at neap tides, as abovementioned; and that the necessary widening these channels, for the purpose of discharge of land waters and navigation, will also furnish a sufficiency of reservoir for taking in the tide for the purpose of scours in dry seasons, when those rivers do not afford a sufficiency of water for that purpose; and as this part of the scheme is still to execute, I would recommend it to be done upon the following general principles:

Ist, then, I am of opinion, that the present clear water-way at the sluice of 70 feet in sufficient for taking in as much tide-water as is necessary for the purpose of scouring the outward harbour, and for filling a channel sufficient for navigation to the towns of Rye and Winchelsea, and for bringing down and discharging the land waters.

2d. I am of opinion, that a greater capacity than is necessary for the purposes abovementioned is hurtful, as a channel too wide will be maintained from filting with greater difficulty; and the taking in too great a body of water will bring in a greater quantity of filt, and will occasion an unnecessary fall of water at the sluice, too great for the quiet passage of vessels; and that the tide falling without, before the internal parts are full to the same level, will occasion a diminution of depth of water for the vessels from the fluice upwards. I would thorefore propose, that the channel of Winchelsea, from the upper end of the new canal to the town of Rye, be widened, deepened, and straightened, so as to be 50 feet wide in the bottom; each side to batter at the rate of 2 feet horizontal to I foot in depth; the bottom to be so disposed, as to make a part of a plane regularly inclined from the lower end of Scotch Flat Sluice upon the Rother, to the cill of the great suice: in which case, as the low cill of Scotch Flat lays about 51 feet higher than the cill of the great sluice, the bottom of the new channel joining upon the new canal at C will be 7 inches higher, and the other end of the new channel D at Rye will be 2 feet 10 inches higher than the cill of the great sluice at the point D; the banks or walls of this canal to be set at least 40 feet from the brink thereof, and to be raised to 25 feet above the cill of the great sluice, to be 6 feet top, to batter 3 to 1 towards the canal, and I to I landwards.

3d. From the point D to make a cut to the north of the town of Rye, to fall into the river Rother at some convenient point, suppose E; this cut to be 40 seet bottom, to agree with the inclined plane aforesaid, its sides to have the same batters as the former, and its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the turnpike road F.

4th. To fix a dam across the river Rother, near below the point of diversion E, and to erect a sea wall from the said dam, to some convenient point eastward, upon the present sea wall of the marsh G, and to carry another sea wall from the said dam westward, to abut upon the turnpike road at F, which dam and walls are to be raised to an equal height with the adjoining wall against the marsh, to be 6 seet at top, and to batter both ways, as  $2\frac{1}{2}$  to 1.

5th. As a bridge will be wanted upon the turnpike road, before mentioned at F, for croffing the canal, I would propose it to consist of 3 arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furnished with two pair of folding gates, pointed to seaward, and 1 pair of ditto pointed to landward; the cills of these gates to be laid even with the proposed bottom of the canal at this place, that is, about 2 feet 10 inches above the cill of the great sluice, and about 1 foot 8 inches below the lower cill, and 2 feet 11 inches below the cills of the navigable chamber of Scotch Flat Sluice.

6th. A navigable fluice to be fixed across the Tillingham channel, at some convenient place within half mile above the bridge at the ferry, suppose at H, of 13 seet 6 inches in the clear, with a pair of gates pointing to seaward, and ditto to landward, with draw shuttles or stakers in the latter, and the walls or banks of the Tillingham channel, from the said shuice downwards, to its junction with the canal before described, to be heightened in such manner, and in such proportion, as is described for the main channel from the new canal to Rye.

7th. A dam to be fixed across the present combined channel of Winchelsea and Tilling-bam, at or near the present new bridge at Rye, suppose at K, and the road to be carried over the said dam; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the canal to Rye.

8th. The channel of Winchelfea, from the new canal to Winchelfea Sluice, for the purpose of navigation, and also to obtain a sufficient quantity of earth for the necessary pose of navigation, and also to obtain a sufficient quantity of earth for the new canal, to strengthening of its walls, to be widened and deepened at the head of the new canal, to see the short of the great sluice, and to be carried upon an inclined plane, so as a see that place; the batters of its sides, the height, to agree with the cill of Winchelsea Sluice at that place; the batters of its sides, the height, the new canal to Rye.

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9th. That in case the diversion of the land waters shall occasion the out-fall of Wenway Stuice to chook up, then a new channel to be cut, and sluices erected, for the discharge of Wenway's waters, above the proposed dam at E, into the Rother.

toth. That in case of the total choaking up of the old harbour's mouth, upon the diversion of the rivers into the new harbour, as is to be expected, then the proprietors of such ground as is to be gained hereby, shall have liberty to sew the same into the new channel, by an out-fall sluice or sluices, to be erected at their own expence, either in the new dam proposed in the 7th Article, to be fixed across the old channel, near the new bridge at Rye, or to erect the said sluice or sluices in any more convenient part of the banks of the new channel adjacent thereto.

with, to be more eligible to carry the Rother into the Winchelsea channel, on the south of the town of Rye; this appears also practicable on the same principles; in which case, the suice proposed at F, should be erected near the place of the proposed dam at K.

# OPERATION of the foregoing constructions.

AS the tide will be stopped in the respective channels by the sluices already erected, and proposed to be erected thereon, I find by computation that the whole cavity of the said proposed channels would be filled through the present opening of the great sluice, in the time of a tide, to nearly the same level within as without the great sluice, by a difference or fall no ways prejudicial to navigation through the same.

That the faid cavity, containing near five times as much water as the present canal above the sluice, will be sufficient for the scouring of the outward harbour in dry seasons, as the land freshes in rainy seasons will be sufficient of themselves according to all appearances. That the navigation for lighters, &cc. up the Breade channel, will remain as it now is; and that the navigation of the Tillingham channel will be put upon a similar sooting, that is, with an opportunity of penning in so much water by the land doors as shall be sufficient for navigation, consistent with drainage; that the navigation up the Rother will not hereby

be interrupted, because 'tis proposed on tide of flood to take in as much water, above the proposed sluice at F, as will float the vessels to Scotch Flat Sluice; but to shut out the top of the tides, which will in effect compleat the drainage of all the present extensive salts included within the cross walls, proposed in Article 3.

That the drainage of the lands by the five waterlings, White Kemp, Guildford, and Wenway shices, will be upon a better footing than heretofore, because having little pen upon them from without, the fluices and banks will be fubject to less repair, and will admit less sea water in the drains by leakage, soakage, &c. and at low water will have a better discharge, because their out-fall channels will be less liable to silt. The new cut below will, in my opinion, be amply sufficient for all purposes; for though proposed only 40 feet at bottom, yet, according to the proportions given, will be 80 feet at top, at 10 feet depth; whereas the cut above Scotch Flat Sluice does not appear to be above 30 feet at bottom, the sum of all the openings of that sluice being but 26 1/2 feet wide, and yet through this capacity is discharged all the spring and down-fall waters from an extensive flat and upland country. Again, though the fum of the openings of the proposed fluice at F is proposed only 11 feet wider than that of Scotch Flat, yet as the cills thereof will lay at a medium of 2 feet 3 1/2 inches below those of Scotch Flat, and about 4 feet lower than White Kemp, which is the lowest of the four upon the marsh wall; that before the water issuing at the sluice F can pen upon the Scotch Flat, or the four other sluices before specified, the capacity of the new sluice, taking width and depth together, will greatly exceed the sum of all the rest put together. I mention those things more particularly, because, for reasons before given, I look upon all unnecessary widths, either in the sluices or drains, to be hurtful, it being to no purpose to dig out canals merely for the sea silt to fill up again.

I must also here mention another advantage to the drainage of the lands dependent on the sluices beforementioned, and that is, the danger of the loss of their present out-fall; for though the land waters will always find a way to sea, yet it does not follow that it must be at such perpendicular height or depth as is consistent with the drainage of the lands; this has actually happened in the course of a sew years to the river at Boston in Lincolnshire; whereas the new out-fall proposed will be always capable of maintaining its original goodness. And the same reasoning will hold with respect to all the other levels which sew into the old harbour of Rye.

I am, however, of opinion, that the tides ought never to be shut in by the great suice so as to pen upon the aprons of any of the suices for drainage, at a time when any of the levels are under water on occasion of rains or other down-fall.

With

An ESTIMATE for compleating the harbour of Rye, according to the plan and

report of J. SMEATON.

With respect to the Winchelsea channel, as an out-sall sluice, as beforementioned, has been erected thereon, within the compass of a sew years, near the town of Winchelsea, which being very properly placed for stopping of the tides, I am of opinion that nothing further is necessary than to strengthen the walls from the new canal to this sluice, as before mentioned, and to keep this sluice in repair; and that no additional sluice on the main channel, between the aforesaid and the new canal, can be attended with any benefit to drainage, and will be an impediment to navigation up to the town of Hinchelsea.

I am further of opinion, that no fluice placed to the east of the town of Rye, by way of taking in the tides into the channels, proposed as aforesaid, from the old harbour, can be of any use, because I expect that the first winter after the diversion of the land waters, the mouth of the old harbour will in a great measure, if not totally, be choaked up by the sea.

From my view of the works already undertaken, I find many things not yet compleated, particularly about the harbour's mouth, the pier heads and the wharfing proposed to extend from the piers to the great sluice, and many things that have gone into disrepair through length of time since the work was done, and for want of letting the sea into the harbour sooner; but as those matters are capable of rectification, I shall at present take no further notice thereof, than in my estimate of the expence that will attend it. And, upon the whole, I am of opinion, that when what has been and is now proposed, is duly executed, that there may be made and maintained 20 feet water at spring, and 14 feet water at neap tides, from the sea up to the head of the present canal, and a proportionable depth as before specified up to the towns of Rye and Winchelsea; and that for vessels, such as those depths of water will suit, will be a safe, useful, and commodious harbour, and therefore advantageous not only to the towns and country adjacent, but to vessels trading through the British channel, and therefore useful to trade in general.

London, February 16, 1763.

J. SMEATON.

#### To raising the east pier head with stone 5 feet higher than it now is, and coping the same with stone, containing 4589 cube feet, = 38. 6 d. including cramps, comes to 803 /. and for repairing the decayed part, fender piles, &c. 1971.; in the whole, - - -1000 . 0 . To raising the stone part of the west pier 5 seet high and 4 feet thick, 1080 feet, at 31.6d. 1891. and for repairs of fenders, 0 0 200 To compleating and making up the additional part of the west pier, between the stone-work and new head, and for fixing a capstan upon the 0 0 300 said head for warping out ships, For repairing and backing up with rough stones the wing, wharfing, ex-300 0 0 tending from the east stone head into the beach fronting the east, To expences in clearing out the harbour's mouth, fo as to be 20 feet deep 500 0 0 m spring tides, - -To 2800 feet running of the wharfing, and securing the banks of the present canal from the present wharfing to the sluice, at 21. per foot, To repairs of the wharfing already done, To securing the aprons of the sluice, above and below, with rubble stone, 875 0 0 containing 3500 tons, = 51. To making 4 wharf-wings for preventing the wash of the water from getting behind the wings of the fluice, containing 140 feet running, 280 0 0 To additional mechanism, in order to make the drain-gates rife with more To carpenters and smiths work in repairing and strengthening the present 100 0 0 great gates, so as to make them more lasting, To capping over the piers of the sluice with Portland Stone, containing 0 0 3797 feet, = 3s. 6d. cramps included, To making a timber draw-bridge over the head of the present canal, for communicating the road as it now passes over the dam from Rys to Hastings, To digging out the channel from the new canal to Rye, containing 261653 3271 0 0 yards, at 3d. To removing the present dam, and making such new ones as will be wanted during the progress of the work, and making up the banks, at least to the height specified in the plan, To widening and deepening the Winchelfes channel, and making up the banks, as per scheme, containing 49573 cube yards, at 23 d. Carried over

Q

				L. s. d.
Br	ought over		-	16465 # #
To cutting a new canal to the north of the town of Rye, from the Til-				
lingbam channel, at the point D, to the Rother, at the point E, being 40				
feet bottom, 16 deep, and 9 furlongs in length, containing 249736	L.	5.	d.	
	3121	0	. 0	
cube yards, at 3d.				
To constructing a navigable sluice and bridge upon the aforesaid canal, of	1800	0	0	
37 feet clear waterway, at the point F,				
To erecting a timber bridge across the aforesaid canal for continuing the	***	o	0	
road from Rye to the ferry,	500		0	
To making a dam across the Rother below the point E,	800	0		
To continuing a fea bank or wall from the dam at E, to marin wall at G.	65	0	0	
To making a dam across the united channels of Winchelsea and Tilling-				
ham, near the new bridge at Rye, at K,	900	-	-	
To erecting a navigable fluice upon the Tillingbam channel, above the				
ferry, as at H, and making a cross bank,	500	0	0	
To making a new drain 95 l. and out-fall fluice for Wenway Crook water,				
	200	0	Q	
105/	2500	0-	0	
To contingent expences upon the whole,			-	
			£.	26751 0 0
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			T C	SEE A TON
February, 1763.			J. J.	MEATON.

SCHEDULE proposed to be annexed to the Act for finishing the harbour of Rye.

Manner how the harbour is to be finished and compleated, subject to alterations, as mentioned in the Act.

THE channel of Winchelsea, from the north end of the new canal to the junction of Tillingham channel near the town of Rye, to be widened, deepened and straitened, so as to be a medium of 50 feet wide in the bottom, each side to batter at the rate of 2 feet horizontal to 1 foot in depth; the bottom to be so disposed as to make a part of plane regularly inclined, from the lowest sell of Scotch Flat Sluice upon the Rother, as it was in the month of February, 1763, to the sell of the great sluice upon the new harbour;

harbour; the banks or walls to be fet at least 40 feet, at a medium, from the brink, and to be raised 25 feet at least above the sell of the great sluice, to be 6 feet top, to batter 2 and  $\frac{1}{2}$  to one towards the canal, and 1 and  $\frac{1}{2}$  to 1 landward.

To widen, deepen and straighten the Tillingham channel from the point aforesaid, so far upwards as shall be necessary to come at a proper place of departure into a new canal, next hereaster mentioned.

To make a new cut or canal to the north of the town of Rye, from some convenient part of the Tillingham channel asoresaid, to some convenient point of the river Rother, the cut to be 40 seet bottom, to agree with the inclined plane asoresaid; its sides to have the same batters as the former 1 it's banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the present turnpike road which leads from Rye towards London; but if any part of the ground shall not be sufficient to allow the batters, slopes and distance of the banks, before specified, then the sides of the canals and banks to be wharfed up or otherwise supported, so to preserve the bottom of the canal of the width before specified, and the banks to be made sufficiently strong to hold in the waters to the same height as before specified.

A bridge to be built upon the same turnpike road for crossing the canal, to consist of three arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be surnished with two pair of gates pointed to seawards, so as to form a navigable lock, and onepair of gates pointed to landward; the other two arches or passages to be surnished each with one pair of folding or falling gates to seaward, and gates to landward. The sells of those gates to be laid even with the proposed bottom of the canal at this place.

To fix a dam across the river Rother, near below the point where its course shall be diverted as aforesaid, and to erect a sea-wall or bank from the said dam to some convenient point eastward, upon the present sea-wall of the adjoining marshes, and to carry another sea-wall from the same dam, westward, to abut upon the aforesaid turnpike road; another sea-wall from the same dam, westward, to abut upon the adjoining wall against the said dam and walls to be raised to an equal height with the adjoining wall against the said marshes; to be 6 seet at top, and to batter both ways as 2 and  $\frac{1}{2}$  to 1.

A navigable stuice to be fixed across the Tillingham channel, at some convenient place within half mile of the bridge. at the ferry near Rye, of 13 feet 6 inches in the clear, within

with a pair of gates pointing to seaward, and another pair to landward, with draw shuttles or slakers in the latter, and the walls or banks of the Tillingham channel, from the said sluice, downwards, to its junction with the canal before described, to be heightened in such manner and proportion as is described for the main channel from the new canal to Rye.

A dam to be fixed across the present combined channel of Winchelsea and Tillingham, at or near the present new bridge at Rye; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the new canal to Rye, and to have the same slopes as the dam aforementioned, to be erected upon the Rother.

The channel of Winchelsea, from the present canal to Winchelsea Sluice, to be widened and deepened, so as to be 20 feet in the bottom; to form an inclined plane, so as to fall 2 feet towards the new canal, from the sell of Winchelsea Sluice; the batters of it's sides, the heights and slopes of it's walls to be the same as proposed for the new channel from the new canal to Rye.

In case the diversion of the land waters shall occasion the out-fall of Wentvay Sluice to choak up, then a new channel to be cut, and sluice erected, for the discharge of Wentway Waters, above the proposed dam, into the Rother.

Proper bridges to be made for communication of the present roads.

## To CAPTAIN PIGRAM.

SIR,

YOUR favour of the 9th instant was duly received, and now comes in course to be considered. As almost two years since I was at Rye are now gone over, without any progress being made in those additional works, which were reported absolutely necessary to be done for preserving the harbour, even in the state I found it, it now behoves you to take vigorous measures, and not be impeded by small matters, least you lose the benefit intirely of what has been done.

That it is necessary forthwith to bring in as much of the back-water as you can procure, appears very evident from what you report, viz. that the new canal is swerved

up, towards the head, 8 feet higher than when I saw it, which is very conformable to what you will find in my report, viz.

"This canal alone, exclusive of the outer harbour, will take in above 200 sail of vessels, but yet does not contain a sufficient body of water to produce the necessary sources below; and surthermore, this part of the canal being liable to silt up, by the deposition of mud brought in by the sea, will, in a sew years, be choaked up, and rendered intirely useless; the silt being gathered at least 4 seet deep at the head of the canal, since July last, when the harbour was opened. What therefore is principally wanting to compleat what I apprehend to have been the original scheme, is to bring the land-waters and freshes of three rivers, that now discharge themselves into the old harbour of Rye, through the new harbour, by which means the whole will be kept clear, as appears to me from the following reasons, &c."

As I look upon the Winchelsea waters alone to be insufficient to preserve in the canal a requisite width of channel sufficient for navigation, the grand object is to get possessed of the Tillingham water as soon as possible; the natural course of proceeding is this.

1st. To secure the banks or walls of the Winchelsea channel from the head of the new canal to Winchelsea sluice.

2d. To cut through the dam that at present divides the new canal from the Win-chelsea channel.

3d. To raise two dams across the Winchelsea channel, one just below, but as near as possible the head of the new canal; the other as near as may be to it's junction to the Tillingham channel, by which means you are enabled to dig out the channel, as directed, from the new canal to Rye.

4th. This done, you remove the two dams, and, with as much expedition as posfible, raise the dam at New Bridge across the united channels.

By this management, you, in the first place, become possessed of the Winchelsea waters, towards making a scour, and also that part of Winchelsea channel that lays between the present head of the new canal and Winchelsea sluice, to add to your reserbetween the present head of the new canal and Winchelsea sluice, to add to your reserbetween the present head of the new canal and Winchelsea sluice, to add to your reserbetween the present head of the new canal and Winchelsea sluice, to add to your reservoir, when you pen in the sea water; and, in the second place, you possess yourself as voir, when you pen in the sea water; and of the great increase of reservoir that will early as possible of the Tillingbam water, and of the great increase of reservoir that will

follow upon opening this new channel and that of Tillingham. With these two you will make something of a figure towards the proposed design, and at the same time bring up vessels to Rye by way of the new harbour.

By this method of proceeding the communication of the Winchelfea and Tillingham waters must necessarily be interrupted during the making this new channel; nor do I know any means of avoiding it, without cutting a fresh channel through fresh grounds, which would not only be a great additional expence upon the undertaking, but only partially remove the objection. If therefore the clamours raised by the seamen and by the country on this occasion are to prevail, I would advise the Commissioners at once to give up the undertaking, and spend no more money upon it; for if the means are not to be used, by which it is to be effected, it is in vain to make any further attempts; but as I can see no material or lasting inconvenience likely to arise herefrom, I will endeavour to satisfy all reasonable and impartial persons on this head.

And first, with respect to the land owners upon the Winchelsea channel, those below the sluice will probably expect to be overslown by the tides rising higher upon them from the new harbour than the old; but it appears, from my levelling notes, taken when there, that when the tide slowed 19 feet 9 inches upon the beacon or staff, at the head of the new canal, it rose within 8 inches of the same level in the Winchelsea channel, on the other side the banks, and that when it rose to 20 feet 3 inches upon the said beacon, it rose within 2 inches of the same level in the Winchelsea channel. Hence I conclude, that in the greatest tides there is very little difference, or possibly higher in the Winchelsea channel than in the new harbour, correspondent to what is usually observed, that weak tides are much spent by a long and intricate course, but when all obstructions are surmounted by a strong tide, that the motion, thus acquired, will list the tides to a greater height in a river, at a distance from the sea, than near it's mouth: but however this may be in the present case, from the matters of sact above stated, it appears that a much greater flow of tide is not to be expected from the new harbour than the old.

In regard to the sewage of the low grounds at low water, it is very evident that this will be improved, because the fall sluice at Winchelsea will then be nearer it's outfall to low water at sea, and consequently it's course being shortened, it will have more fall in proportion, and thereby penning less dead water upon the apron of the sluice, the water will discharge itself faster through the same openings. It may possibly be objected, that the mud is gathered in the new harbour to a greater height than it's

present

present bottom, at the same distance from the sluice, which will be an obstruction; but the land water will soon cut a channel through the loose mud.

I take it for granted, that whenever these waters are first turned this way, a channel will be opened through the mud, which, once done, there is no doubt to be made but that the water will not only maintain itself a channel through the fresh mud, of as great dimensions as it does in the solid ground, but will even deepen the whole, on account of it's greater rapidity.

The same reasons will also take place with respect to the lands that lie upon, or sew, by the Tillingham channel, both before and after their re-union with the Winchelsea; because, before they will have the whole channel to themselves, and after they will have both a shorter and a better.

It therefore remains that I give my reasons why I don't think the navigation will be spoilt up to Rye Strand.

The harbour or place where ships now lie is intirely within the Tillingham channel, and which they now find sussicient; it therefore follows, from the established laws of nature, that the same causes producing the same effects, the Tillingham waters will maintain the same channel below the new bridge that they do above.

It may be objected, that the united channels below the new bridge, being wider from the union of the two rivers, this channel may grow more shallow, as well as contract in width! I am of opinion that it will not; for since there is constantly matter sloating in the water capable of choaking up all the channels, if the land water did not drive it out and keep them open, why does not the Tillingham channel widen and grow more shallow? but suppose the channel was to grow somewhat more shallow, yet, grow more shallow? but suppose the channel was to grow somewhat more shallow, yet, for the time, it will be wanted the same expedients might be made use of as is done in several other channels, viz. a hedgehog to raise the mud occasionally, till the sides shave contracted themselves to proportionable width. Some small alteration in point of have contracted themselves to proportionable width. Some small alteration in point of width may also be expected at the old harbour's mouth; but as the effect can only be in width may also be expected at the old harbour's mouth; but as the effect can only be in that part of the Winchelsea channel, from the new bridge to Winchelsea sluice, with the whole body at a full sea, we shall find the proportion so small as to be almost insensible whole body at a full sea, we shall find the proportion so small as to be almost insensible in its effects; but if by the objections made by the masters and owners of ships at Rye, they in its effects; but if by the objections made by the masters and owners of ships at Rye, they have the present channels are not to be diverted or altered till the mouth of the new harbour

harbour is effectually scoured, and every thing ready to bring up thips to the town of Rye by the new harbour; as this is in the nature of the thing impossible to be done but by means of the diversion of the said channels, they thereby desire that the effect may precede the cause, which being contrary to nature, they at once strike at the root of the undertaking, and therefore, as I have already said, if these arguments are to prevail, the best way is to give the thing over at once.

A great deal depends upon the expedition with which these works are performed; for if, while the new channels are digging, the new haven is contracting in width, for want of a sufficiency of back water to keep it open, by such times as they are compleated, the new haven will be afresh to dig, and the work become endless.

Difference of circumstances alter cases. Two summers are now elapsed since my scheme was made, and 8 feet more of mud in the new canal; it is therefore not only necesfary to pursue vigorous measures, but to take such methods in performing the work as may the soonest put it in a state of maintaining itself; I would therefore, at the first outset, advise, that the new channel from the new canal to Rye be not dug but 35 feet, or at most 40 feet bottom, with flopes as steep as they will stand, as suppose 1 to  $1\frac{1}{2}$ , according to the quality of the matter, but never steeper than 1 to 1; such a channel will answer all the purposes of navigation effectually; will save a very considerable sum in the first construction; will save a good deal of time, which is now become very valuable, will focner bring the utility of the undertaking to a proof, and will be as large a channel as the Tillingham can in any degree maintain; which will therefore prevent its swerving and contracting in width, while the other channels are compleating for bringing in the Rother ; and when that is done, in case the rivers themselves do not make it of the width sufficient, it may be compleated by tide work, after the more necessary parts of the work are brought to bear. Nor is there any doubt but that in the mean time it will take the Rother and Tillingham land waters, as the former go all through Scotch Flat Sluice, which it has been remarked is no wider, all the passages taken together, than 26 1/2 feet; and as to the Tillingham, its capacity when the tide is checked by the fluice proposed to be built thereon, will be contained in one of the slopes, for even a 35 feet bottom, with the steepest batters, will produce a 65 seet top, and a 40 seet bottom, with batters of 1 to 11, will produce a river 85 feet at the grass.

It will here be naturally enquired, whether I would build the sluice proposed upon the Tillingham, before it is made to communicate with the new harbour? I answer, not, for as the tides will go up in the same manner, whether proceeding from the new harbour or the old, the use of that sluice will be entirely to check the tides from coming in too rapidly

rapidly at the great fluice by having too much room to expand; but as this will not be the case till the communication with the Rother is made, till then it will be useful by enlarging the reservoir.

With respect to the works at the harbour's mouth, you know it was always my opinion, that an attempt to stops the beach absolutely from moving from the west towards the east would be a sruitless and endless task ; for let the groins be extended to what length they would, they would fill with beach = fast as they could be raised, and the overplus drive over into the harbour's mouth; I therefore thought it best to let the beach drive away gradually as it came, and in consequence that the extension of the west head could be of no further use than to steer the beach clear of the east head till the wind came so far out to fouthwards as to tend to heap up the beach upon the shore, rather than drive it along the coast, which end seemed to me very sufficiently answered by the pier as it stood when I saw it, especially with the low groin extended therefrom southwards; for it always seemed to me, that in case the pier was carried out further than absolutely necesfary for this purpose, that the quantity of beach that will always be left scattered about the mouth of the harbour, after every fouth-westerly gale of wind, as it were in its passage, will be too far in the expanded space without the east head, to be carried out by the scours, and then a southerly or south-easterly gale brings it right into the harbour: these have been my notions about this uffair, and which have been before expressed.

But as I have not yet found any folid ground-work, upon which I am able to determine how the fea will act in all possible cases; and as you have been pleased to try the experiment of a different procedure, I would advise you not to lower those groins till you are very sure they are upon the whole hurtful; and if so, the thing determines itself; consider also, if hurtful to the harbour, how far they may be beneficial to protect the beach from being carried away to the eastward of the east pier, or how far that may be protected by other means. It is one thing to advise an erection not to be made, and it is another to advise its demolition when made, before it has been sufficiently tried.

You further inform me, that the old timber wharfing, by getting bare, tumbles down faster than they can put it up new. Let me once more recommend to you the use of rubble stones for desending the sides of your harbour instead of timber, not walled, but thrown in so as to form a natural slope. The effect thereof on many repeated trials I thrown in so as to form a natural slope. The effect thereof on many repeated trials I have never found to sail; and I may say that I saved the two piers of London Bridge, whereon the great arch rests, from being undermined, and thereby the arch from salling, whereon the great arch rests, from being undermined, and thereby the arch from falling, whereon I was at Rye. I am of opinion, that had 300% been applied in time in rubble

Vot. I.

ble stone behind your east pier, as mentioned in my estimate, that it would have saved greater expences, and been a lasting repair; but this, as well as several other derange. ments that happened in the mean time, I suppose must be imputed to the unseasonable stoppage of the bill the first season it was applied for.

I am, with great respect to the Commissioners,

SIR,

Your most humble servant,

J. SMEATON.

Austhorpe, December 29, 1764.

#### RIVER WENT.

Minutes of a view of the river Went, by JOHN SMEATON.

HAVING taken a view of the river Went, Yorkshire, from Went's Mouth to Norton Mills, there appears to me a sufficiency of fall for draining not only the valley of the river Went, but of those lands that have their sewage into the same, and which appear to be of a very considerable extent. It appears to me, also, that the principal defects of the present drainage, arises from the great crookedness of the river, joined to its being too shallow, and a general want of capacity for taking off the water from so great a tract of country; the out-fall fluice is also of too small a capacity for the drainage of such an extent of country, but seems nearly adequate to the present drain; the mechanism of its present doors, however, is very defective, and they are too low. The river Dunn's water having over-topped the same, the banks near the sluice, which ought to defend the valley of the Went from the floods of the Dunn, being too low and out of repair, have suffered great quantities of water in the late floods to pass into the same. The drainage of the Went's Valley is further annoyed by an influx from the river Dunz in time of great floods, through a low sade of ground between Brafit Common and Flaxley Carr, and from thence proceeds down by way of a drain called the Fleet into Went, a little above Topham Ferry; for as Brafit Common is frequently overflowed by the land floods of the Dunn, (and sometimes even by high tides, according to my information,) and as Ash Carr, which borders upon Brasit Common, and is the highest part of the flade, lays lower than the furface of the dam in high floods, the water makes its way through the drains and hedges in great quantities into Flaxley Carr, and from thence by the Fleet Drain into the Went as aforesaid. There seems to have been formerly some attempts to have prevented the water of the Dunn from taking this course, by raising a fence bank somewhat more considerable than common, between Ash Carr and the inclosures that lay east and north-east thereof, which so far at present answers the purpose, that by raising dams with sods, &c. in the gateways and low places, a great deal of water was prevented from passing, that otherwise would have passed this way during the great floods, last Christmas; and, was this bank raised, so as to be of sufficient height and strength, would effectually answer the purpose; but the same purpose would be more conveniently answered by constructing a new bank, with proper tunnels, for the drain across the head or south end of Ash Carr, from the inclosed ground that lays upon the west side thereof, and abutting upon Brasit Commen, extending the same along or paral-

R 2

lel to the fouth hedge of the inclosure, on the east side of Ash Carr, which also abute upon Brafit Common, to the side of Brafit Fields, being in length, by estimation, about 250 yards: this bank, in one polition or other, not only appears necessary for securing the drainage of the Weat's Valley, but will greatly improve that of a confiderable tract of land laying in the slade aforesaid, particularly about Flaxley Carr, which, except a part of the top waters which are run off down the Fleet into Went, and by another drain leading to the outlide of Syke House Bank to the fouth end thereof into the Dunn, depends altogether upon a small tunnel called Hell Wicket Clough, no more than 8 inches by 121, for running off their bottom waters through Syke House Bank into the internal drains, and thence into the Dum by Black Sea Clough, which clough runs three days on the decline of a flood before Hell Wicket Clough is opened. It further appears to me, that the drainage of Brafit Common, and the lands dependent thereon, will receive no prejudice by the bank before proposed, because Brasit Common lays several seet lower than Ash Carr, both which drain the contrary way, or southward into the Dunn, the present sence bank before mentioned being the line of partition of the two drainages, at all times, except in extraordinary floods as aforefaid.

Although from this view now taken, I am convinced of the practicability of draining the valley of the Went, yet the depth and capacity of its main drain, together with the requifite height, and dimensions of its banks and sluice, cannot be ascertained without an actual level taken thereof; and, in order to ascertain the quantity of land concerned in this drainage, as well as the general directions and length of the drains to be new constructed or amended, and thereby to come at a correct estimate of the same, it will be necessary to take an actual survey of the river Went, from its mouth to Norton Mill, describing the banks, sluice, and main drains that fall into the same, upon a sufficient scale to express the particular loops of the river; and also an outring or flood line of such parts of the several lands that drain into Went, that are liable to be flooded thereby, or for want of a sufficient sall into the same; which outring does not need to be traced with that correctness, that the river itself ought to be laid down, but preferving, however, the general bearing between the river and its correspondent part of the outline. The taking of the levels I can myself undertake, if the gentlemen concerned desire it, the surveying part I would recommend to be done by a skilful land surveyor.

Womersley, 31st March, 1764.

J. SMEATON.

N. B. As the present river is wanting in capacity, and its course so meandering that it is likely to measure by its loops double the right line, I apprehend it will be less expence

expence to make a new cut the greatest part of the length, than to sufficiently enlarge the present river, which cut may be so contrived as to strike a general mean between the properties.

MINUTES taken upon the River Went, in levelling the same, from the River Dunn, at Went's Mouth, to Norton Mills, the 7th, 8th, and 9th of May, 1764, by John Smeaton.

Places of observation.	Rife of the ri-	Widths taken at promifeuous places.	Depths taken at promifeuous places.	Heightsoflands above the wa- ter's furface,	Rife of the fall winter's flood above the ri- ver's prefera: furface.
From the farface of the river Duna to the threshold of Went's doors, which was $7\frac{1}{2}$ inches under the water's surface there,	Ft. In.	Bridge 14 9 other places from 10 to 18		Near the Dunn	Floods of Dunu 13 2
From Went's doors to Hooden }	0 9	from 12 to 18	from 0 8 to 3 0	mean height 6 to 5 \frac{1}{2}	Went's floods about 6 feet.
From H. d. a Dyke to Bazon }	3 41	from 12 to 19	from 3 o	from 4 0 to 1 6	from 4 o
From Bawn Croft to Topbam }	o 9½	15 0 bridge 14 2	from 1 8 }		
From Topham Ferry to Lake's }	3 63	from 14 0 to 16 0	from 4 0 to 2 0	from 1 6	from 2 6
From Lake's Month to Clough Bridge, at the low corner of Norton Common,	1 9	from 13 0 to 14 0	from 3 0 to 1 2	from t 3 to 0 0	trom 3 0
From Clough Bridge to the departure of the Went from Stubb's Common,		from 16 0		from 0 6 }	
From Stubb's Common to Nor- }	3 7	from 90}	from 1 0 } to 1 8 }	from 2 0 }	
From Norton Bridge to the }		double courle.		from 4 0	to 3 0
From the river Dunn to Norton Mell,	19 0				

Hence

Hence it appears, that from the floor of Norton Mill Race, to the surface of the river Went at Clough Bridge, there is a fall of 7 feet 4 inches, and from thence to the threshold of Went doors a fall of 10 feet 10 inches, which added together make a fall of 18 feet 2 inches from the floor of Norton Mill to the threshold of Went doors, and from thence to the furface of the Dunn, there was a fall of 10 inches; but as it was a neap tide, and not then low water, I suppose the Dunn would ebb a foot lower, so that from the tail of Norton Mill to low water in the river Dunn at Went's Mouth at a neap tide, in summer, we may reckon a fall of 20 feet.

The dimensions of the sluice called Went's doors, are as follow:

		feet.	inche
The width between the walls at top is -		12	0
Ditto at bottom	-	10	- 0
The width of the opening between the gates at top is		. 8	7
Ditto at bottom	-	7	3

## WOMERSLEY DRAINAGE.

The REPORT of JOHN SMEATON, Engineer, concerning the Drainage of the low grounds in the manor of Womersley, belonging to STANHOPE HARVEY, Efq;

HAVING taken a view of the lordship of Womersley, with respect to the drainage thereof, the 16th and 17th of July, 1764, it appears to me as follows.

- 1st. That the middle of the manor, through which the drain called Bradley Dyke passes, is in general the lowest part thereof.
- 2d. My own observation also agrees with information, that the piece of ground called Bradley, is the most liable to be flooded of any in the lordship.
- 3d. That from the run of the water in Bradley Dyke, which in many places is pretty quick, at the same time that this drain is narrow, shallow, crooked, and much obstructed, there seems to be a fall of several seet in the course thereof from Bradley to the brook called Lake.
- 4th. That there is also a considerable sall from the mouth of Bradley Dyke, to the beginning of Mr. YARBOROUGH's lands, bordering thereupon at the Calf Garths.
- 5th. That the sewer called Blowell, which in general skirts the lordship on the north, and falls into Lake at the eastermost point thereof, is very well calculated to answer the purpose of a catch-water drain, to carry off the barrier waters, without suffering them topass into the internal parts of the manor; but passing in general through higher lands feems not well adapted for main drain, except for some particular parts, which will hereafter be pointed out.
- 6th. That the rivulet called the Beck, whose continuation after it joins Bradley Dyke is called Lake, and which makes its way through the southern side of the lordship, is in like manner well calculated for a catch-water drain; but as the Beck likewise passes. through higher lands, and also carries the springs and flood water from the upland country, it is therefore less adapted for the purposes of a main drain for the interior parts. Hence of the manor.

Hence I am of opinion, that the lordship in general will be drained in the best manner by a middle drain, calculated more effectually to answer the purposes of the sewer called Bradley Dyke.

In order to give this drain all the consequence possible, I would propose its out-fall to be as low as may be, that the declivity in the Lake arising from its being loaded with the upland waters, as well as from its crookedness and want of dressing, may be in a great measure avoided. For this purpose, I would recommend that the out-fall of the new drain be carried down to the eastermost part of an inclosure, called Old Ing Spring, that is, to the commencement of Mr. YARBOROUGH's lands, which begin with the Calf Garth next adjoining; from this point I would propose to carry the new drain to Bradley, as much as may be in a right line, without interfering with other property, to pass as much as may be through the lowest grounds, and so as to be as central as posfible; with this view I would propose to carry it from the eastermost point of Old Ing Spring, marked in the plan a, obliquely for a few rods till it meets the hedge-row between the Old Ing and Old Ing Spring, and to follow that hedge-row to b, from thence to pass in a straight line to the south-east corner of the Sodgels at c, to follow the south hedge thereof to d; from thence in a straight line through Bell Fields, Stocking Pobill Spring, and Stockings, to the fouth-west corner of Ox Stockings, between Grayson Close and Bradley Dyke at e; from thence in a straight line cross Broad Oak Spring Closes and Broad Oak Spring, to the point f, between Mr. SAVILLE and Lady BELT's lands; from thence in a right line cross Hodihon Crosts to the road, and to cross Bradly Dyke, a little above Bradley Bridge, to the Sodgells, at g; and from thence in a right line, so as to avoid Bradley Dyke, into Bradley, at the east corner thereof at b; from hence branches may be carried at discretion to the more remote parts of the lordship, as for example, one from b, across Bradley westward, to i, and from thence cross low moor to k, where it will receive the waters from the springs rising near that point, and also will conveniently receive the drainage from Northings. Another branch may be carried from the said point b, cross Bradley north, through Pipper Carr, and the rest of Woodball Farm, to the point I, where it is calculated to receive the down-fall waters from the large piece of low ground called Gale.

With respect to Blowell, the Beck, and Lake, I would advise them to be continued in their present course, and their banks to be made up, and strengthened where necessary, towards the interior parts of the lordship, in order to keep out the barrier waters from penetrating thither, and thereby not only contributing to flood the lands, but to load the internal drain.

The bottom of the proposed drain at its out-fall, I would advise to be made as deep as the bottom of the Lake thereabouts when scoured, and to be carried upon a dead level to about the length of Stocking Pobill Spring; from thence to advance upwards upon a regular inclined plane, so as to be full 5 feet deep on entering Bradley at the point b, to be 6 feet wide in the bottom, and the sides to slope or batter 1 foot backwards in 1 foot high; so that supposing the mean depth to be 6 feet, it will be 18 feet wide at top, and there will be cube yards in 1 yard running, and in every acre of 28 yards long 224 cube yards, which at  $1\frac{1}{2}d$ . per yard will cost 28 s. an acre, or 1 s. per yard running; that is, 88 l. per mile, and for 2 miles and 1 surlong, which is the length of the proposed drain from the point a at Lake, to b in Bradley, will cost 187 l. exclusive of clearing the ground of wood and roots, and exclusive of such bridges as may be necessary where the roads cross the same, which are four in number.

The branch drains need not be above 4 feet bottom, carried upon a regular inclined plane, so as to be at their upper end at least 4 feet below the surface of the lands to be drained thereby.

That part of the lordship about Wye Lands, Kidcoats, &c. which now drain into Blowell, will drain much better into the new proposed drain, by a cross cut from South-Lane, through Katele's Cross, to the drain between Bell Fields and Hare Springs; but the lands lying more eastward about Mitchel-Lane, may continue to drain into Blowell, being by this road nearer this out-fall, provided the obstructions between Hodsham Garths, where this drainage comes in, and the out-fall of Blowell into Lake are effectually remedied, and that drain deepened from the bottom of Warsield Wood upwards to the said point, in which space a good deal of fall is at present lost.

These methods steadily pursued, and strictly adhered to, will in my opinion put the lordship in as good a capacity of drainage as it is capable of, and which will be fully effected when the river Went is made a sufficient sewer for the general drainage of the lands lying thereupon.

N. B. The business herein attended to is the main drain and the diversion of the barrier waters; but it must be understood, that the benefit arising therefrom cannot sully take place till the smaller ditches and sewers that divide and intersect the lands are thoroughly scoured, and such surther cross cuts made to lead the water from low places by the most direct road into the main drain, as experience and surther observation shall shew to be necessary.

Womersley, 18th July, 1764.

J. SMEATON.

The

# MISTERTON SAS AND SNOW SEWER.

The REPORT of JOHN SMEATON, Engineer, upon the case of Misterton Sas and Snow Sewer Drain, belonging to the honourable the Participants of Hatsield Chace, from a view taken thereof 14th August 1764.

about half a mile from the Trent. This fluice is furnished with two pair of doors, both pointed towards the Trent, so as to compose a lock for navigation of vessels, serving them to pen from the tide water into the drain, and thereby occasion either pair of the doors to be shut. The neat width of this sluice is 17 feet 8 inches, and its height above its threshold a little more than 16 feet. The question concerning it is, as I apprehend, whether an addition of water-way at the Sas, in time of floods, will be of service in reducing the height, and consequently the weight and pressure of the water at those times against the great bank called Vicar's Dyke Bank, which defends the level of Hatfield Chace against the floods of the river Idle.

## OBSERVATIONS.

Ist. The time that I was at the Sas the tide was out, all the doors open, and the land water had its free course through the same; the depth of water running over the threshold of the doors to landward was 4 seet 7 inches, and the water's surface had a fall from head to tail of the sluice of above  $4\frac{1}{2}$  inches, consequently the threshold of the doors to Trentward were below the surface of the tail water 4 seet  $2\frac{1}{2}$  inches.

exact observations upon the state of the waters here during the course of last winter, informed me that the 21st of May last (which was the day before the moon quartered) he observed that the tide rose at the Trent 5 seet before it sensibly rose at the Sas, the tail water at the Sas being then the same height as this day, viz. 10 seet 10 inches below the S. E. corner of the land wall at the Sas; now had there been no run of water through the Sas, then the water would have been upon a level from the Trent to the Sas, and of consequence,

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consequence, it would have appeared that the threshold of the stuice would have been  $9\frac{1}{2}$  inches higher than low water mark at the Trent; but as the run of water through the stuice was then considerable, as it was this day, it follows that as soon as the water begun to find any stoppage at the sluice to its discharge into the tail drain by the rising of the tide, that the water at the sluice would begin to swell or rise, though it still preserved its motion downwards, and consequently that it would begin to swell before the water of the Trent was got up to the same level; now if we allow 2 or 3 inches for this declivity from the Sas to the Trent, which must be added to the former  $9\frac{1}{2}$ , we shall have about 12 inches that the thresholds of the sluice lay higher than low water mark at the Trent.

3d. Mr. Crompton also shewed me a mark that the land waters were at on the head of the sluice the day before the bank broke at Idle Stop last winter. This mark I sound to be 3 feet 5 inches above the present head water, and consequently (allowing  $4\frac{1}{2}$  declivity on on the tail) 5 feet  $9\frac{1}{2}$  inches above the present tail water. He also shewed me a mark, being the height of the water then in the tail of the Sas, when the doors were open and running with a full bore; and this mark I sound to be 5 feet  $1\frac{1}{2}$  inch above the tail water, consequently the fall of water at the Sas was then at its greatest stream 8 inches.

4th. The width of *Vicar's Dyke*, at a medium between the Sas and Idle Stop, was about 38 feet at the water line, the depth at a medium from 3 to 4 feet, and the water having a smart run all the way, I suppose by estimate that the fall of water from Idle Stop to a single star was at least 1 soot per mile; that is between 3 and 4 feet, as I estimate the distance between three and sour miles.

# DEDUCTIONS.

AS it appears from the preceding observations, that the pen or head of water at Misterion Sas, occasioned by want of capacity, never exceeded 8 inches in the greatest Misterion Sas, occasioned by want of capacity, never exceeded 8 inches in the greatest extremes of floods; hence it would seem that the flood water was never raised more than extremes of floods; hence it would seem that the flood water was never raised more than extremes of floods; hence it would seem that the flood water had been as wide as the river; 8 inches higher than it would otherwise have been, had the Sas been as wide as the river; 8 inches higher than it would be quite just, in case the flood water had been confined on and this conclusion would be quite just, in case the flood water had been confined on both sides, so as to be obliged to go off as fast as it came down; but as it was at liberty to foread

spread over the lands, where it did not find a passage to its out-fall so fast as it came down, it must keep accumulating till the discharge was equal to the influx.

Now it must be allowed that had the Sas been of a greater capacity, it would have run a greater quantity of water upon a given declivity; consequently, from the first approach of floods by continually running more water, the accumulation would have been lefs, and the rife of water less against the banks, which in all probability would have preserved them from breaking at Idle Stop. It is by no means however hence to be inferred, that though the fluice had been as wide as the river, that the floods would have been carried off as fast as they came; for, in the first place, whenever the Trent floods or tides overrode the land waters, the sluice could not run at all, let its capacity be what it would; and at other times, as the effects depend jointly upon the capacity of the sluice to discharge, and upon the drain to bring the waters to it; and as Vicar's Dyke appears to be desective in point of depth, it must have had a considerable share in the obstruction: for as from observation the 4th, there appears a considerable fall from Idle Stop to the Sas, this cannot be otherwise occasioned than by a rise of the river's bottom, which thereby holds up the water, and must obstruct its free passage in all degrees of sloods: whether this obstruction has gradually arose by means of weeds, &c. or it has been originally made so, may be a question; but we may reasonably suppose it was originally made so; for was this part of the river deepened, it would draw off the water from the higher parts of the river in dry seasons to a greater degree, so as to incommode the navigation, and perhaps at some times to put an entire stop thereto for want of water over the shoals above.

Upon the whole, then, I look upon the enlargement of the water-way at Misterion Sas, to be an adviseable step, and that it may be done in a proper degree relative to the drain, even upon a supposition that it was deep enough, we are to enquire what capacity the sluice ought to have had.

The width of the drain 38 feet at the water line, supposing it to carry 3 feet water, it will batter 3 feet each side, and will have a 32 feet bottom: this ought to have been the width of the water-way, supposing the thresholds laid as low as the water-mark. The greatest extremes of sloods rise per observation 10 feet above the thresholds of the sluice, and consequently 11 feet above low water mark, so that 11 feet multiplied by 32, the proper width, given 352 feet area, for the water-way; but 10 feet the present height, multiplied by 17 feet: 8 inches, present width, gives 177 feet area nearly; which, being nearly half of the former, it shows that the present water-way should be doubled, if laid at the same depth.

This enlargement may be made three ways:

1st. By four draw-gates of 4 feet 6 inches wide each. 2d. By two pair of pointed doors, placed near together, one pair pointed to Trent, the other landwards, which latter may be gaged to the height requisite for navigation.

3d. By one pair of doors pointed to Trent, and by a fixed over-fall or weir, gaged to the height necessary for navigation.

The doors in the 2d and 3d method may be the same width as the present Sas, the threshold being laid at the same depth, or about 16 seet wide if laid down to low water mark; but in the 3d method, supposing the height necessary for navigation to be 5 seet above the present cill, then the length of the crown of the over-sall must be 35 seet, for then when the sloods rise 5 seet above the top thereof, there will be 175 seet area of waterway, which, with 177 seet at the Sas, will be 352 seet, required.

The first method has preserence in point of expence, but the gates will want opening on the approach, and shutting on the decline of a flood; and as these are not sudden, or of very short continuance, may easily be done.

The second method will be nearly as cheap as the first, and will need attending at the same time.

The third method will be somewhat more expensive than either of the sormer; will be preserable on account of needing no attendance; will do the same office on the extremes of sloods; but will be of less service in discharging the water on the decline of sloods; which, though of no immediate consequence to the banks when below a certain sloods; which, though of no immediate consequence to the banks when below a certain sheight, yet in case of succeeding rains, the nearer the former are run off, the more room for those that sollow.

That the third method will be inferior in point of discharging water on the decline of sloods, appears thus: suppose the water reduced so as to make 1 soot over the crown of the weir, its area of discharge will then be 35 seet, whereas it would make 6 seet over the threshold of the gates or doors, and upon 17 seet 8 inches wide, 106 seet area: the threshold of the gates or doors, and upon 17 seet 8 inches wide, 106 seet area: the weir indeed is not confined to 35 seet long, but in this case it would be required nearly three times as long to do the same thing.

The ready discharge of the water on decline of floods will be very beneficial to the drainage of the lands, which drain into Idle or Vicar's Dyke, and therefore ought to contribute if done on that principle.

## ON SNOW SEWER.

THIS drain leads the down-fall water from that part of the level adjacent to Idle Stop, &cc. on the fouth fide of the ifle of Axholme, to a place called Ferry, where there is a fluice called Ferry Sluice, by means of which the water of this fewer is discharged into the river Trent, and is the highest sluice upon the river belonging to this level. and consequently has the least natural fall; it was however necessary, on account of the drainage of that part of the level laying on the fouth fide of the island, the high land of which abuts eastward on the river Trent, and thereby prevents a natural communication of internal drains to carry the waters of these parts to a lower point upon the Trent, without carrying them a great way round about the west end of the island.

This drain is from 15 to 20 feet wide at the water line, and when I was there carried a full body of water, which at three miles distant from the sluice had for the most part a flow run, except in some places where it appeared to be sanded; there the motion was fomewhat more lively; but as the drain was in most places horse belly deep, quite free from weeds, and no capital obstructions, there appeared upon the whole to be no remarkable less of fall. As we approached nearer the sluice, the water was in a manner stagnant, the doors being shut by the tide: in this state, the water was just beginning to get upon the surface of the commons from a mile to a mile and a half west of the sluice, which hence appears to be the lowest. I observed at the same time that the water was 3 feet 6 inches deep upon the land apron of the fluice.

The sluice consists of two doors of 6 feet water-way each; but the tide being in, and the sluice-keeper absent, there was no coming to the knowledge at this time how the thresholds of the sluice lay with respect to low water mark in the Trent; accordingly orders were given that this should be taken at a proper opportunity, and the following were in consequence sent me.

				Feet.	Inches.
Above the threshold,	-	de-r	-	2	2
On the floor, -	~	-	-	2	9
The fall of water,	48	-	-	5	9

Mr. Forster suspecting the above might not be rightly taken, desired me to go over again, but, being engaged at that time, fent my clerk, who took the levels the 9th of September, tember; being the day before the full moon, and consequently between the neap and spring tides: his account was

The furface of the water in the Trent at low water, abo	we the top of		Feet.	Inches.
to the sheafhold a		-	0	2
Thickness of water going over the threshold,	-	-	0	6
He was further informed that at dead of neap the furface	of the Trent,	at		
low water, was lower by	_	_	0	6 :
low water, was lower by				

From the last observations it appears, that the threshold of Ferry Sluice lays higher than low water mark at dead of neap (which here it feems makes the lowest-water) by 4 inches; and allowing 7 inches for the height of the threshold above the sloor, (according to the former observations) and taking this from 3 feet 6 inches (measured by myself) upon the land apron, there will remain 2 feet 11 inches descent from the surface of the lowest lands to the threshold of the sluice, and 3 feet 3 inches from ditto to low water mark, neap tides. Hence it appears, that as the fall is but barely sufficient to furnish the means of drainage, the whole ought to be constructed upon the nicest principles, and kept in exact order.

It does not appear to me, that any great matters can be done till the fluice is rebuilt, further than an effectual scouring of the drain, and deepening where sound necessary; and if banks of  $2\frac{1}{2}$  or 3 feet high were raifed against the low commons, it would prevent their being overflowed by the water coming down from the westward, when the Trent floods over-ride the drain, and keep the doors constantly shut; but then tunnels with valves next the drain must be laid through such banks, to take off the down-fall from the commons, where the water of the drain becomes lower, otherwise such banks will be a means of retaining the water upon the lands, as well as in preventing their being overflowed. A further temporary expedient might be, to turn as much of the water as may be from the western parts, towards Aughborpe Sluices, which, laying lower upon the Irent, afford a better fall.

When Ferry Sluice is rebuilt I would advise its floor to be laid lower by 1 foot 6 inches, that is, I foot 2 inches below low water mark at neap tides, and to be made at least 15. feet clear water-way, to be shut by a pair of pointed doors.

I know this practice will be opposed, upon a supposition, that being laid to low it will not run fo long, and will be more liable to warp.

But it is very plain, that was the orifice a mile deep, it would always run when the water within was higher than the water without, and that at all other times the doors would be shut; and this will equally be the case if laid high, but with this difference. that by being dammed up by the floor and threshold, it will not run when the water of the drain is lower than the threshold, though higher than that of the river. To make the advantage clear, let us suppose I foot water going over the threshold of the present fluice, which being 12 feet water-way, the section of the column of water passing will be 12 square seet; now suppose the water at the same height within, and the floor 1 foot 6 inches deeper, then it would run with the same velocity in a column 2 feet 6 inches in thickness and 12 feet wide, which makes 30 feet area of the column; so that in this case the sluice would run as much in one tide as in the other it would run in 2½ tides; but if the width is increased to 15 seet, the area will be 37 ½ seet, so that it will then run more water in one tide than the present one in three. Again, when the present sluice is run dry, there will be a column of I foot 2 inches thick upon the threshold of the new, whose area will be 17 1/2 square feet, which will vent as much water as the present sluice will do when it has 11 inches water upon its cill; so that the construction proposed will not only, at all heights of the water, run much more in quantity, and thereby vent the water quicker, but run it down to a lower surface than it possibly can be by the present construction.

With respect to ways, suppose the old and new sluice both warped up to the same height to both without, and the water at the same height to both within, that is both to act from the same drain; it is plain that the old sluice cannot act till a channel is made through the warp, whose bottom is lower than the surface of the water in the drain; it is also plain that the new one will begin to act at the same time; the only difference will be, that as the warp will lay 18 inches deeper against the doors of one than the others, there may be some little more trouble in clearing the warp from before the doors, so as to suffer them to open at the very first starting; but after each has begun to run, and cleared away a part of their warp, the new sluice will always have the advantage of the old one, because, by carrying a greater body of water, it will open its channel quicker and more effectually keep it open at low water, so long as it continues to run.

The sluice being thus constructed, it will be necessary to deepen the drain, making the bottom 15 seet wide, and to carry it as near as possible upon a dead level with the threshold for 2 miles; from thence it may be regularly inclined towards its head: this being done, in my opinion, it will do its duty without suffering any of the lands to be overslowed by the Trent.

Austborpe, 19th September, 1764.

J. SMEATON.

# EARL OF KINNOUL'S LANDS.

The REPORT of JOHN SMEATON, Engineer, concerning the Works for the Defence of the Lands of the Right Honourable the Earl of Kinnoul, laying upon the Rivers Ammon and Tay, North Britain.

If. IT appears to me that the greatest part of the damage done by sloods upon these lands, is owing to the shallow channel of the river Ammon, and the insufficiency of its banks.

2d. That, in order to cure these desects, it will be necessary to carry a bank from point of land marked out, about half an English mile above Ammon Bridge down to the east abutment wall of that bridge, and from the said east abutment to carry a bank coasting the east side of the river Ammon, at proper distance to the point of land laying between the mouth of the Ammon and the Tay, which bank ought at a medium to be about a feet high and about 20 feet of base, the slopes to be sodded on both sides, or about a feet high and about 20 feet of base, the slopes to be sodded on both sides, or

3d. That as the aforesaid work will be of equal and immediate advantage to the grounds now liable to be stooded by the waters overflowing the banks of the Ammon, which are without the border of the estate of the Earl of Kinnoul, (and upon which the which are proposed to be made) therefore the proprietors to be at a joint expence said banks are proposed to be made) therefore the proprietors to be at a joint expence with the Earl of Kinnoul for the compleating thereof.

4th. But in case the said proprietors do not chuse to be at their proportion of expence, then I would advise the Earl of Kinnoul to make good the breach that has been made in the land contiguous to the bulwark erected at the end of the new road leading from in the land contiguous to the bulwark erected at the end of the new road leading from in the land contiguous to the bulwark erected at the end of the new road leading from Perth to Ammon Bridge, and to make the whole effectual, to take down the remains of the present bulwark, and to make the whole of rough or rubble stone from the quarry, the present bulwark, and to make the whole of rough or rubble stone from the quarry, the present bulwark, and to make the whole of rough or rubble stone from the quarry, the present materials thrown together bank sask fashion, so as to slope  $1\frac{1}{2}$  seet base to I soot perpendicular to I soo

line the banks or abutments with rubble for 1 rod above, and 2 rods below the bulwark at each end; which fald bulwark is intended to confine the waters of the Ammon or Tay in moderate speats from slowing down the old road, but in high sloods to break the rapidity of the current, and to admit the same to have an easy passage over the bulwark.

Earl of Kinnoul and the town of Perth, in order to preferve and regain the lands from the incloachments of the river before which it has been raifed, I am of opinion that the lands might have been fecured in a much easier and cheaper method, as hereafter described, and with respect to the regaining of lands they could never be worth the purchase: it further appears to be built of very bad stone, and therefore will be subject to a considerable annual repair, greater than will support the banks intended to be supported thereby; yet as some good has been produced from it, though not adequate to the expence of building or maintaining it, yet I would not advise any erasement thereof, but to leave the same to such events as the floods and weather may produce, and which in a state of rubbish, by keeping the channel of the river at a distance, will tend to lessen the repairs, which otherwise might be necessary on the said banks; and whenever the river shall begin hereafter to make any depredations on the land, to apply the cure immediately to the part affected, which I would advise to be done in the following manner:

Let a quantity of rubble stone be brought from the quarry, the more angular, rough, and irregular the better, and at a medium as big as a large cabbage; let as much be thrown up against the broken place (almost as steep as it will lay) as will form a natural flope against the bank as high as ordinary floods reach, or as the surface of the lands where lower, floping away the land above the rubble where higher, observing to avoid all jetties and protuberances as much as may be, so as to give the water as free a passage as possible. In general I would advise my Lord Kinnoul, in case of breaches or incroachments upon the land by this or any other river, not to have recourse to jetties, or walls of masonry, but to line the banks with rubble thrown in, so as to form a natural flope, and the length of the work the nearer it is to a parallel direction with the current the better, by this means the quantity of materials necessary to form a jetty, breakwater, or bulwark (which being defigned to refift and oppose the current must be made stronger) being disposed along the face of the bank, will in general be sufficient to defend the whole length that could be expected to be effected by the jetty; and with this difference, that the edge formed by the jetty itself, generally forms a pit or incroachment upon the land just below; whereas the work dispoted in a parallel direction to the current equally protects and equally refilts; so that the wreck and fullage of the river in time filling up the interstices

interstices of the rubble makes it grow firmer, whereas the constant action of the content upon the weakest part of a bulwark or jetty, viz. the termination thereof, puts it in a constant state of waste and decay.

By the application of rubble we have stopped the most formidable breaches where the river has had its course through, by means thereof we secure our banks and the aprons of our locks and dams upon the river Calder, over which last the water in time of sloods has much greater rapidity than the natural current of the Tay possibly can have in the neighbourhood of Perib; in short, we make use of it in all our desences upon the Calder, and have never found it to sail. I know it will readily be urged, that the Tay being larger river than the Calder, that what will do upon the one, may not do upon the other; it is true, that the Tay is wider river, but it does not appear to be more rapid, that depending chiefly upon the fall, which in the Calder is above 8 seet per mile for above 20 miles together, that we are concerned with it, nor does it appear that the Tay in time of floods rises to a greater height above its common surface. Hence I infer that the action of the Calder upon its banks is as great as that of the Tay upon its banks, because the quantity of this action depends upon the height and rapidity of the water acting immediately against them, and not upon that which passes by at a distance from them, so that the width of the river is totally out of the question.

In general I would advise my Lord Kinnoul to be as sparing of these kinds of works as may be; for without a great deal of land be got or saved by a moderate quantity of work, though the method I have chalked out is the plainest, easiest, most durable, and cheapest of any thing I know, where stone can be procured at a moderate expence, yet that land would come very dear that would require covering with rubble.

Perhaps it may be suggested that danger may arise from letting the great bulwark go to ruin; for when in that state, if an inconvenience should happen to arise, it would be much more expence to repair, than to keep it in repair. But this I apprehend to be quite otherwise; for a mass of rubble thrown promiscuously together, upon the ruins of the present bulwark, will be more lasting than the present one can be with its present materials and form, and can always be repaired by addition.

Upon the whole, it appears to me, that the greatest damage done, or likely to be done, to my Lord Kinnoul's estate at this place, arises from currents of water topping the banks of the Ammon, and running over the surface with great rapidity, thereby taking away the earth, wear gullies, and leaving tracts of barren gravel in its room, which

which will be the most easily prevented by embanking the Ammon as before described, and stopping the mouth of any such gullies as appear to lead the waters upon the land; yet notwithstanding this will not prevent the back water from returning up the slades from below, and standing upon the land to the same level as the Tay at the places of communication; however, the water there being in a manner stagmant, the ravage above mentioned will be prevented; but a total prevention of the floods from coming upon the lands can no otherwise be effected, but by embanking the whole round, both against the Ammon and the Tay, so as to be slood proof against the greatest extremes, with a proper sluice to let out the down-all and soakage waters when the sloods are over; and this, though I look upon it as a prasticable work, yet the difference of rents upon the quantity of grounds concerned, does not seem to encourage an undertaking so considerable.

Having mentioned the expediency of banking against the Ammon, it may be understood I looked upon the Ammon waters to be the sole cause of the overflowings already mentioned: but the case appears to me thus; when the Tay is shooded, it would revert upon the channel of the Ammon to the same level, though no current was to come down the Ammon at all; and were the banks of the Ammon lower than those of the Tay, (as they really are about Ammon Bridge) the Tay would run up the Ammon, and first and most strongly run over at the lowest places, viz. near Ammon Bridge; but if at the same time that there is a shood in the Tay, there is one in the Ammon also, as must often happen to be the case, the current of the Ammon being stopped by the Tay, the Ammon must then be forced to rise to a greater height, till it can over-ride the Tay's water, and for that cause rising to a greater height, will the more plentifully overshow its banks; but was the Tay low while the Ammon was in a shood, I don't apprehend much mischief would ensue from the Ammon alone.

With respect to Bussey Mill, I find that with the quantity of water issuing from the boot at the time I saw it, there is a power, when well applied and the machine rightly managed and used, of grinding a Winchester quarter of wheat per hour, and that such an erection, if done here, would cost from 4 to 500L

Austhorpe, 13th Dec. 1763.

J. SMEATON.

## RIVER DEVON NAVIGATION.

Some Points relative to an intended Navigation upon the River Devon, thated by Lord CATHCART, and answered by John Smeaton.

Sir,

IF I rightly understand you in our late conversation, your opinion upon the points stated to you was as follows.

betwine Allos and Cambus, were cut with a canal, the fides properly floped and faced with rough flone, (as you may more particularly emplain in the margin) and the prefent channel of the Forth allowed to remain as it does, such canal, the banks being of a height to contain the tide, would not endanger the adjacent lands by bringing more water that way than is intended, will have no occasion for flood-gates, and will be an effectual improvement to the navigation, by avoiding the Thrask shallows, and other impediments.

My Lord,

THE points stated by your lordship contain the substance of what passed betwixt your lordship and me in conversation, therefore, to avoid repetition, shall note in the margin what I have occasion to enlarge upon, or wherein your Lordship seems to have misundershood me.

1st. In this particular I understood your Lordship that the Thrafk shallow is a flat shallow at low water, not of such an height as to pen the water above it, but merely an impediment to navigation, through want of depth. This being the cafe, a canal cut through the ilthmus will have no other effect than here deferibed, and the fides of the canal being floped from the proportion of z to t, to 1 to 1, as the foil may happen to be from a loofe earth or gravel to a firm clay, and being covered with rubble quarry stones (suppose one foot thick), in as to make a compleat cover, this will not only defend the bank from the action of the current, but of the waves occasioned by the wind; but in case the sheal abovementioned makes a confiderable pen, so as to determine the current much more strongly through this new canal than through the course of the river, it will be necessary to defend

2d. That if the river Devon was navigated by Sir John Erskine, from the Cobble Crook to Cambus, by means of fluices on Tilli Body Bridge, that navigation may be better effected by the canal and lock proposed than it could have been by the sluices, and the ground through which the canal passes, viz. from Minostrie Lint Miln Dam to Tilli Body Bridge, being clay and perfectly level.

3d. That from Cobble Crook to Sauchie, there being only two small fords in the way, the navigation may be effected by one lock and dam at the lowest ford, in case it should not be sound better to avoid the fords by cutting from deep water to deep water, and making a channel behind the fords; but that this expedient, which is the best, cannot take place if the present fords act as dams, and the new cuts

defend the bottom also with stones, to prevent the action of the water from deepening the fame, and thereby sapping the foundation of the stone sacing, and in consequence bringing down the banks and widening the canal. In case the pen should be very considerable, it would be necessary to build a lock upon it; but the determination of this matter depends upon the length of the canal, and difference of level of the surface of the river at the head and tail thereof, taken at low water, when there is no fresh in the river, as also upon the quality of the ground forming the bottom.

2d. There is no doubt but that locks are preferable to simple sluices.

3d. I beg leave to add, that if a dam is built upon the ford, or the upper ford be supposed to act as a dam, a canal with a lock upon it, brought down so as to drop into the river below the lower ford, it will also equally answer the end if sound most easily practicable. Also, if instead of joining the deeps by cutting a channal behind the fords, the fords themselves be removed, or channels through them be made,

should have the effect of letting down the river, and creating other fords in parts where the upper part of the navigation is intended to go.

the navigation by locks out of the river at Old hauchie, and raising it into a canal, upon the level of the river above Tillicoutery Dam, to be carried in the line and direction of Lord Carried in the line and direction of Lord Carried into the pipes where it crosses the Devon) and there to be carried in an aqueduct bridge over the river, and continued to the dam, and from thence to the foot of the Rack Miln Dam, where there must be locks to surmount the said dam, in case the navigation is carried on to Vicar's Bridge.

5th. That the level of the stretch from Sauchie to Melloch soot is proved by Lord Cathear's aqueduct and the present state of the Devon, which is already navigable betwixt Tillicoutery Dam and Melloch.

6th. That the rifing of the river in times of flood, so as to overflow the aqueduct bridge, does not infer any danger, either to the bridge or adjacent lands.

made, this will also answer; but in this case, care must be taken to make the channels on such side where the principal tendency of the water is to act in stoods, otherwise they will be liable to be thereby filled up again.

4th. This feems to be the method from what was described to me upon the plan; but as it is scarcely possible to form adequate notions without ocular inspection, much must be left to the judgement of him who executes, in respect to the choice of the ground.

5th. Certainly, supposing the said aqueduct to be carried upon a level.

oth. It must be supposed that the dimensions of the water-ways, breadth and depth taken together, under the aqueduct bridge, must be such as to vent the water as fast as it comes in at extremes of sloods, and also the ice in winter, otherwise great damage may ensue both to the works and adjacent lands, unless a certain length of the side walls of the bridge that sustain.

fustain the canal are very strongly capped with stone, and left lower than the rest, for the water to slow over like a dam; but this expedient I would not recommend to be used, if it can be possibly avoided. N. B. I don't at present remember why the passage of the river cannot be obtained by raising a dam in the river below the intended place of crossing.

7th. Agreed.

7th. That, upon the whole, as thus represented to you, the navigation of the Deven, and the improvements of the navigation of that part of the Forth, between Cambus and Alloa, seems very practicable, and, from the nature of the levels, at a moderate expence, considering the length of the navigation.

vigation bills, and their consequences when passed into acts, it is your fixed opinion, that the execution can neither be answered for, nor depended upon, in the hands of trustees, and that the only safe and sure way is for the proprietors of coal within reach of Devon, and Mr. Abercrombie, to be the undertakers, or for Lord Cathcart to be the undertaker, with a proviso in savour of the other coal proprietors and of Mr. Abercrombie, in case they shall chuse to recede, and naming a number of Commissioners to be

8th. This I have enlarged upon in my letter from Newcastle; I have only to add, that in this case the adventurers should be fixed down to take a reasonable toll for coals from the other coal owners, who may not in their present situation chuse to be adventurors themselves, otherwise the proprietors of the navigation may chuse to lose those tolls altogether, to prevent the others from working their collieries, which would be a detriment to the public.

9th. I forgot to ask the dimensions and size of the boats proper for the carriage of coal, and how deep water they will require.

referred to, and to judge betwixt the un-

dertakers and other proprietors in all

questions that may arise now or here-

after, with respect to damages, &c. in

consequence of this act, by which means

the parties interested in the toll will

attend to the execution; and as the

toll never can be suffered by the un-

dertakers to rife to the price of land

carriage, the difference, whatever it is,

is fo much faved, and therefore a benefit

to the public.

As also whether is a better method to land the coal from the canal on the pier, and load them from thence on board the ships, or to let the boats down into the river by locks, and put them on board directly from the lighters.

Your certifying the above to be your opinion, or marking on the margin where I have mifunderstood you, with some explanation for the satisfaction of the other persons concerned in this bill, relative to the 1st, 6th, 7th, and 8th articles, with your Vol. I.

9th. The fize of the boats used for carrying coals is various in different places, and differ in fize, shape, and draught of water, according to the convenience of the place; but I apprehend that such boats as are principally used in the Torkshire rivers, will answer as well as any for such a navigation, as proposed by your Lordship, viz. 54 feet long, stem and stern post included,  $13\frac{1}{2}$  feet wide, and 3 feet draught of water; those will carry from 20 to 30 tons, according as they are more light or heavy built.

If the ships were always ready to be loaded, when the boats brought down coals, it would certainly be the most advantageous to lay the boats alongside the ships; but when the ships are not ready, they must necessarily be landed upon some quay or wharf common to both,

opinion upon the 9th, will very much oblige, Sir,

Your most obedient humble fervant, CATHCART.

London, Feb. 11, 1765.

both, which I apprehend should be covered like the coal staiths at Newcastle. Whether the quantity that can be delivered alongside the ships, in proportion to what cannot, together with the advantage of an open communication of the canal with the Forth, for the conveyance of other goods and merchandize, will make it worth while to make the necesfary lock, is a matter of convenience that can only be determined upon the place, by those well acquainted with the nature of the trade thereof.

The cases stated, considered with my answers thereupon, contain the opinion upon these matters of,

My Lord, Your Lordship's most humble servant, J. SMEATON.

Austhorpe, 20th April, 1765.

QUERIES, &c. communicated by Lord CATHCART, relative to a navigation on the Forth, November 5, 1767.

BY the Report of Messes. WATT and Morison to the Board of Police, it appears. pears,

That a navigation may be opened at a small expence from the valuable woods, lime and state quarries of Aberfoil to the bridges of Aberfoil upon the Forth.

That it may be continued from thence to Cardrofs, by a lock below the ford of Cardross.

That it may be continued from thence to Frew by a lock below the ford of Frew.

That from thence the river is navigable to a rocky ford called Craig Anet, betwixt the Bade and Drip Coble, which is two feet higher than Craigforth mill-dam, which last is three feet higher than the cruives of Craig forth, which are four feet above the neap tides, in the lower part of the Forth.

That a dam of three feet should be added for the sake of deepening the water, as far up as the Frew, which water so raised would be 12 seet above the neap tide.

That a canal near a mile in length, from a point above the Bade, across level ground of a clay foil, with a lock of 12 feet fall, would compleat the navigation from Aberfoil to the tides-way at the new mill of Craig forth.

And that the navigation from thence downwards may be shortened about seven miles by four cuts, as expressed in the plan, below Stirling Bridge.

It appears by Mr. SMEATON's report to the proprietors of the Devon collieries,

That Cambus, with proper improvements, may be made a very convenient port for exporting sea coal, and for accommodating ships in that trade.

That the river Devon may be rendered navigable from Mellock foot to Menstree Lint mill-dam, which space includes five collieries.

And that the navigation may be continued from Menstrie Lint mill-dam, to the tideway in the Forth at Cambus.

Menstrie mill-dam is 12 seet above the neap tides, therefore on a level with the water above the three-feet dam at Craig Anet, in the Forth, projected by Mr. WATT.

Suppose  $2\frac{1}{2}$  feet added to the height of each dam, the water in the Forth above Craig Anet, and in the dam above the Lint mill-dam, will still be equal, and  $14\frac{1}{2}$  feet higher than the neap tides.

The ground is clay, and very level from Menstrie Lint mill-dam to a point betwixt the bridge at Stirling and the new mill at Craig forth, where the banks on both sides are pretty high; and Mr. WATT's canal may be brought, upon very favourable ground, to a point opposite to it.

Suppose an aqueduct bridge of a proper dimension, erected across the Forth, betwixt these two points, (the distance being 300 feet) there will be dead water from Frew to the Lint mill-dam, by which the upper part of the Forth will have an easy, short, and open access to the Devon collieries, and also have an opportunity of dropping into the tides-way at Cambus, by locks of  $14\frac{1}{2}$  feet fall, the advantage of which, considering how much lime-stone, slates, wood, &c. must come down, and how much coal must go up the Forth, including the consumption of the town of Stirling, and the inhabitants of those parts of the country that come through Dumblain; and that the lock at Craig forth new mill, and a great length of navigation, and the loss of time in waiting for the tide, will be saved, is extreamly obvious.

The only circumstance of doubt is the practicability and expence of the aqueduct bridge, the length being 300 feet, and the bottom of the river clay, and far above rock; if it is executed in stone, the number of piers which it will require, as the level will admit of so small a rise for the arches, and the soundation which must be piled, it is apprehended must render the expence enormous. If it is executed in wood, upon the plan of Julius Cæsar's bridge, which is well-adapted to resist ice, or other sloating bodies, or upon any better more modern construction, it is apprehended it would come much cheaper, would stand against the force of the stream, and of the ice in winter, and would not be affected by the land sloods, which cannot rise to the sole of the aqueduct, but must be liable to the expence of repairs to which a slone bridge would not be subject.

Mr. Smeaton, who is acquainted with the nature of the rivers and country adjacent in question, and skilled in every expedient that may facilitate the junction of the two level canals, by an aqueduct, is desired to say,

at the Lint mill-dam, or the lock at Craig forth new mill, seems, upon the face of them, the most eligible for the inhabitants of the upper part of the Forth?

2d. If the aqueduct plan feems the most eligible, what data will be necessary to furnish Mr. SMEATON with, to enable him, at his leisure, to make out a design for the bridge.

3d. Does Mr. Smeaton think that the boats recommended for the Devon, drawing three fect water, of 13½ feet width, and 56 feet long, will answer all the purposes of the Forth boats, or would it not be proper to allow for a foot more draught of water, in order that their states, &c. may be carried coastways, and that the locks and canals be for that purpose proportionably deepened?

4thly. Suppose the aqueduct bridge rejected, and the lock at Craigforth Mill adopted, will it not be expedient to make the sour cuts in the Forth, as marked in the plan; and if any, but not all, which of them?

5th. The ditches from Tillibodie Bridge to Manner Pow are from 8 to 10 feet deep, and about 12 feet wide, and are on a level with the Devon, at Tillibodie Bridge, and with Sir John Erskine's canal at Cambus, would it not be right to build a lock at Manner Pow, and to enlarge these ditches, that Upper Forth boats might get, by that tract, to the collieries, whereby upwards of 6 miles navigation would be saved?

ANSWER to five Queries concerning the improvement of the Navigation of the River Forth from the River Devon upwards, communicated by the Right Honourable the Earl of CATHCART, in a Letter of November 11th, 1767, to John Smeaton.

object in view, then the long canal, from above Stirling to the Lint Mill Dam, upon the Object in view, then the long canal, from above Stirling to the Lint Mill Dam, upon the Object in view, then the long canal, from above Stirling to the Lint Mill Dam, upon the Object in view, then the long canal, from above Stirling to the Lint Mill Dam, upon the Object in view, then the long canal in that case would merit serious Devon, seems very well adapted for that purpose, and in that case would merit serious consideration, how far the aqueduct bridge, over the Forth (which indeed seems the only distinctly) might not be (under the specified circumstance of elevation) an executable distinctly) might not be (under the specified circumstance of elevation) an executable steems; but if the expence and dissiculties of executing such a bridge there, as well as seems of land, cutting bridges, and other contingencies attending the proposed the expences of land, cutting bridges, and other contingencies attending the proposed

canal be considered, and that at last it will not save above 5 miles \* of distance, though none of the loops below below below are supposed to be cut; if, on the other hand, the advantages arising from a free and open navigation to all parts of the Forth below, for all kinds of trassick, we put in the other scale, I cannot hesitate to say, the advantages being considered with the expence, and probability of trade, that it appears to me, on my present view of the proposition, more eligible to lock down into the Forth, near Craigsforth new mill, and below that to keep the river.

# 2d. This is answered by the first.

3d. If the vessels were made of greater draught of water than 3 seet, and wider than 13 feet 6 inches, they would undoubtedly be more safe in navigating the broad part of the Forth, and coasting, and could venture, and keep out in worse weather; but such vessels, as described for the Devon, not only go in the narrow rivers in Torkshire. See, and down to Ilull, but even go out to sea, and cross the Lincohnshire washes to Spalding for corn, to be carried in the same vessel to Leeds, Wakefield, and Halifax; but as it is obvious that if the bulk of the vessel is increased, it will occasion greater expences in executing the locks, cuts, canals, &c. it may therefore be worth while to consider, with the degree of trade that is probable, whether it may not be eligible to save a capital that must thereby be expended by changing: for though the vessels above-mentioned can, and do go as before set forth, yet the bulk of trade is carried on by changing vessels at Armine, that is as soon as the river is capable of receiving sloops of 50 and 60 tons.

Ath. The most important object in making artificial navigations, is to avoid dead stoppages by want of water. &c. In many principal navigations in England, vessels are frequently stopped in dry seasons for one, two and three days at a time, sometimes for a week together. Now, if they had a certainty of going at a particular time of tide, twice in 24 hours, they could fuit their times accordingly, and would be content to go several miles about, if they had a certain passage, rather than lie stall so long together; for this reason, cuts are seldom made merely and simply for shortening distances; and though in the district under consideration the river is remarkably crooked, yet, as the rest of it, both above and below, is but little better, it may deserve a terious consideration whether it is worth while to make any of the cuts proposed below stirling; for as, according to the plan I have, the difference of distance is but about 5 miles, with the cuts and without them, the Engineers would therefore do well to consider, from actual admea-

surements of the respective lengths, and levels taken, how deep, how wide at bottom and top, each cut will be required, in order that they may be materially more passable than the present fords; and to effect that, how deep they will be required to be dug below low water, what land must be cut and covered; these things being ascertained, and proper estimates made from the price and quantity of excavation, the price and quantity of land, the charge of pumping water while the digging is going on under level, and the damages that may be done by the river's breaking in while the works are going on in that fituation, also the charge of making dams to turn the water from the cuts, or if none, the time lost in getting the tracking horses across the old loops; I say all these things considered, and estimates sormed from particulars, will soon direct you, whether from the probable quantity of trade, the expence of any, all, or fome of these cuts, will be balanced by the time in the passage respectively saved. The two upper ones seem the most advantageous, the rest in order as they are lower; but it will be right to have a power in the Act to make any of these cuts; that after the necessary canals, locks, &c. are made, if it shall appear from the quantity of trade, and the goodness of the funds, that the thing is eligible, there ought to be a power of doing it without a fresh application.

5th. The expediency of this step consists in the facility in doing it, because the advant we will wholly consist in the trade with the Devon; for it will not be worth while for a vessel at the mouth of the Devon, and going up the Forth, to make use of this passage, vessel at the mouth of the great loop, she will be thrown about only  $t\frac{1}{2}$  mile more than because, in going round the great loop, she will be thrown about only  $t\frac{1}{2}$  mile more than the artificial passage, in which latter she would have to pass two locks.

It is to be observed, that by a double entry into Devon the leakage will be double; and if made use of as a passage up and down the Forth, each vessel will expend two lockfulls, except in cases of meetings.

Ausburge, November 21, 1767.

J. SMEATON.

Lord Catheart's Queries relative to the River Devon.

IVI R. SMEATON to confider the Cambus, and the river below the Cambus, and to give his opinion, whether the Cambus can be made a proper port of exportation in great coals, and if it can, by what means, and at what expense.

Objections. Want of depth of water, expence of making new port, loss of time to thip-masters to come so much further; danger from ice in winter.

If either impracticable, or too expensive, Mr. SMEATON will consider whether the coals cannot be carried in boats down the Devon and Forth to Alloa, and there shipped for exportation.

Objections. Coals carried down to Alloa by water cannot be folded there without great expence, but must be loaded from the lighters, which ship-masters object to, for reasons perhaps srivolous, but will best be collected from themselves, and judged of by Mr. SMEATON.

If coals brought down the Devon can be exported either from the port of Alloa, or of Cambus, Mr. Smeaton will then consider the best method of rendering the Devon navigable, from Mellock soot to the Forth, either by a canal, or in the bed of the river, or partly by one, partly by the other, calculating the expence of the whole, and specifying the dimensions of boats, what they are to carry, and how to be drawn.

The fize and dimension of boats will depend upon the use intended; if they are not to be let into the Forth, they may be very long, very narrow, and very shallow, which will reduce the expence of the canal. If intended to go down to Alloa, or up the Forth, they will not admit of the same construction.

N. B. The possibility of going up the Forth by water from the collieries would be a great conveniency, because were the navigation opened above Stirling Bridge by locks at Craig forth, Frew, and Cardross, all the country on each side the Forth might, as well as the town of Stirling, be supplied by water-borne coals from the Devon collieries.

If Mr. SMEATON finds any species of navigation practicable and adviseable, he will favour the coal masters with his ideas of the proper Act of Parliament to be petitioned for; and of the places, proportion, and manner of collecting tolls, and manner of shipping the coals either from boats or quays; and if he will undertake, or recommend an undertaker for the whole, or the locks only, and on what terms.

To this may be added a remark of Messrs. MACKELL and WATT lately made; that is, that a canal may be carried upon a dead level the whole way from Tillicoutery to a point opposite to the schoolmaster's house at Alloa, sollowing the foot of the rising grounds

the whole way, that it will be about 30 feet higher than the sea, and may either be carried betwixt banks across the stat grounds, which is not far, to the shore, otherwise the stat ground may be cut to bring the Forth up to the low grounds.

This would fave locks and waste of water as far as Tillicoutery, and might be joined by canal from Mellock Foot, the level of which would be a very little higher, and might require a lock.

			Feet.	Inches.
	-	-	18	10
-	-	-	19	6
ge,	-	-	39	6
			77	10
	z- ge,			18 19

X

The REPORT of JOHN SMEATON, Engineer, concerning the practicability and expence of making navigable the River Devon, in the county of Glackmannan, from Mellock Foot to the River Forth.

THE river Devon falls into the river Forth about  $2\frac{1}{2}$  miles above, or to the west of Alloa, but according to the turns of the navigation, up Forth, about  $3\frac{1}{2}$  miles. There are several valuable collieries upon the slope of the hills that decline towards the river Devon, the coals of which are now carried to Alloa over land, in order to be put there on board vessels capable of carrying them to all parts where wanted. The more easy carriage therefore of those coals, from the collieries to the shipping is, as I apprehend, the principal object of the present proposed navigation.

At the mouth of the Devon the extreme spring tides are said to rise 20 seet perpendicular, and at such tides the water slows one soot higher than the top of Cambus Quay, which is an old quay, at which formerly coals were shipped, about a surlong within the mouth of the Devon. The common neap tides are said to rise within sive seet of the top of the said quay, and that then there is 12 seet water in the river Devon opposite the said quay. When I was there, the morning of the 20th of November, 1766, being the fourth day after the sull moon, it appeared that the mark less to the last tide was as high as any that had been that spring, and what might be called an ordinary spring tide: this I sound had been within I soot of the top of the said quay; and consequently, being 4 feet higher than the ordinary neap tide mark, made 16 feet water in the river opposite the quay. At the time I was there it was almost low water in the Forth, and then the current of the Devon run with a considerable declivity towards the Forth, having a fall of not less than 2 feet.

The declivity of the bottom of the river from Cambus Quay to the Forth appears pretty regular; the bottom opposite to and above the quay seems to be mud, intermixed with large tumbling stones; these stones being removed, the mud would wash away, so that I look upon it as very practicable to make 2 feet more water at Cambus Quay than at present, that is, to make 14 feet at ordinary neaps, and 18 feet at common spring tides.

If more water than the above should be requisite, I should look upon it as more eligible to dig out a new channel and harbour from the Farth, which may be done on the west side of the Devon, the ground there being low and siat, and gently rising from low water mark; this work may, therefore, be done at moderate expence in proportion to such a work, but yet must, in digging, walling, &c. amount to considerable sum, more than would be necessary to rebuild and enlarge the old quay and deepen the river, as aforesaid.

To the fafety of the place there feems to me no material objection; for as to ice in winter, it cannot do much harm, as it must be much broken in passing the bridges and dams before it gets to the Cambus. It is no peculiarity of the river Devon, and is the case, more or less, with every sea port which has the advantage of being scoured by series fresh water river, which is in itself very desireable.

In going up the Forth from Alloa to the Cambus, the navigable channel of the river makes one large half moon, but as it is in general sufficiently spacious for vessels to turn, this case also differs little from what is common in other tide rivers; it will undoubtedly be some hindrance to vessels going  $3\frac{1}{2}$  miles surther up, but as this can hardly ever be attended with more than one tide loss of time, and often without the loss of a tide, it may as well be said that the coals ought be carried down to Kincardine Road, to prevent the possibility of the loss of a tide in going to Alloa. The principal impediment in getting betwixt Alloa and Cambus, for vessels of burthen, is occasioned by a shoal called the Frask; and this arises not so much from want of depth of water, as from the narrowness of the channel; for in sounding the river at low water the day above specified, we sounded in the channel over the Frask no less than 5 feet, which, though the shallowest place between Alloa and the Cambus, seems yet very sufficient passage, at all lowest place between Alloa and the Cambus, seems yet very sufficient passage, at all lowest place between Alloa and the Cambus, seems yet very sufficient passage, at all lowest place between tide.

This shoal seems to consist of a ledge of stones which lays almost across the river from S. W. to N. E. confining the channel close in with the point, which is an unnatural situation for the channel, but arises from the greater softness of the ground in that part where the channel is. As this shoal is short, according to the direction of the channel, where the channel is. As this shoal is short, according to the same in width. There it seems very practicable to remove the stones, so as to increase the same in width. There is at present a sufficiency of width, when proper beacons are set, for the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set, so the passage of vessels is at present a sufficiency of width, when proper beacons are set.

This shoal may also be avoided by cutting through the neck of land; but if the great depth that such cut will be required, (the ground seeming there 18 or 20 seet higher

higher than low water) the depth to which it must be carried below low water, and the great width that it must have in the bottom, to make it a more eligible passage than by the Frask, be considered, I believe it will appear that the canal may be extended to Aliva for almost as little, if not less expence. It perhaps may be expected that if the cut is made narrow, and down to low water, that in time it will wear itself wider and deeper, and so indeed it may, but whether this will happen in the compass of seven years or twenty, or whether it will ever happen, so as to be (as already said) a more eligible passage than the Frask, I think is out of the power of any man to say with certainty; for it is to be observed, that till it becomes much wider than the Frask and equally deep, it will be more difficult to turn to windward through it on account of its greater length.

As the natural declivity of the river from head to tail of this supposed cut is very little, unless a dam was put across the main river to force the current through the cut with some considerable velocity, the water could not in its natural state be expected to operate very speedily; and as the width of the river through its several channels in this place is very considerable, such dam would be very expensive, would obstruct the navigation while the new channel was wearing larger, and by depositing of the matter and diverting the present channel, there is no saying but that after all a shoal might be formed in some place where now there is none, as troublesome as that we would mean to avoid; for these reasons I cannot, in my present view of the matter, recommend this division of the river from its present channel.

With respect to the dimensions of the canals, cut out from the course of the river Devon, they depend upon the kind and sort of vessels to be employed, and the sort of vessels will again be determined by the uses to which they are to be applied.

If the vessels are to be employed merely in bringing down coals from the collieries to the quay, where the ships load without going into the Forth, vessels long, narrow, and shallow, may be used with advantage, but if intended to go up and down the Forth, they will require a different construction.

It feems to me, that if the navigation be limited to the canal only, without going into the Forth, it will be attended with many inconveniencies, but that it will be of more general use, if capable of containing vessels capable of going up and down the Forth, as well as of navigating the canal; for by this means vessels may be loaded at the Cambus Quay, or at Alloa, as may be most suitable to the sea vessels to be loaded,

or they may be carried up the Forth to Stirling, and up to Gartmore, in case the navigation above Stirling is compleated, which if confined to the winding course of the Forth may be done at a very moderate expense, as I have sormerly shewn in my report on the proposed canal from Forth to Clyde.

The very extensive trade up the river Aire and Calder in Yorksbire, which passes under Ferry Evidge, and of which coals is the principal article, is carried on in vessels of 56 feet long, slem and stern, 13 feet 6 inches wide, and drawing 3 feet water at a medium; in very dry times in summer they load 6 inches less, and in winter 6 inches more. These vessels at 3 feet draught of water carry, by reputation, from 20 to 25 tons, but of neat dead weight 28 tons; they are generally drawn by one horse, and make way nearly two miles an hour, stoppage at the locks included; though sometimes, for the sake of expedition, and when there are freshes in the river, and the vessels going against stream, they make use of two.

These vessels not only navigate in the narrow rivers, but go round into the Trent to Gainsborough and Newark, and frequently down the Humber to Hull. This fort of vessel, I apprehend, by the same rule, would not only go down to Alloa, and deliver their cargoes there on board ships, but would occasionally go into the Carron, and through the great canal, in case the same should take effect.

By this means, if a large ship meets with contrary winds, or comes in at such a time as to expect being neaped at the Cambus, she may be loaded at Alloa from the boats, in the same manner as all the ships at Newcastle and Sunderland are loaded from the keels there, which carry 21 tons each; on the other hand, when there are no ships that want loading at Alloa, or they happen to be brought down faster, then they are shipped at loading at Alloa, or fent away in the same bottoms to other places up or down the Forth, they will be deposited in the coal-yard at Cambus, ready for the vessels that come up thither for a loading.

The dimensions of the Calder cuts for the vessels above described were, 16 feet bottom, the sides sloped 5 feet for 3 feet of perpendicular, and carrying 3½ feet of water; now in carrying canals upon a dead level on the decline of hills, the ground is seldom now in carrying canals upon a dead level on the decline of hills, the ground is seldom for free from irregularities, but that it requires extra cutting in some places, and extra banking in others, which, as it would be impossible to determine exactly before the exebanking in others, which, as it would be impossible to determine exactly before the execution, as every variation, though but for a few yards, would vary the dimensions, must be allowed for according to the judgment of the artist; to make allowance therefore for the

common inequalities of ground in the present case, I compute upon a cut of 6 seet deep, that is, supposing the water  $2\frac{1}{2}$  seet within soil; not that I expect it to be so in the general; but as in many places the extra cutting will be considerably more, and the designation of the ciencies remain to be made good by so much labour, I make that supposition in order to come at the mean value.

Upon these general dimensions I have computed the expence, upon a supposition of an entire canal, except where it is proposed to come into the river, for the sake of crossing the same, to get the eligible ground, which amounts to the sum of 9357 l.

2d. Supposing the river to be made use of in the general from Tillibodic Bridge to Sauchie new engine, with short cuts to take off loops and place the locks, in this case, though far less apparent work, yet as the disadvantage of placing the locks, well as of constructing them, and laying their foundation below the level of the river, as it will require a lock more, a greater price for each lock, a greater depth of cut, and, on account of greater depth, as well as drainage of water, a greater price per yard of digging; I say, all those being allowed and computed, as in my judgment they ought to be according to the following estimate thereof, this will make the whole stretch from Tillibodie Bridge to the elbow of the river above Sauchie old engine, near Tillicontery Burnsoct, to amount to 47931. whereas if done by canal, according to the first supposition, it will cost 51831. the difference being 3901. in savour of the river navigation; but if it be considered, that following the river increases the length near 1½ mile in 6½ miles, and that the works themselves will be perpetually in greater hazard from sloods, and need more repair, this difference does not appear to be worth the saving.

As I observed the ground very capable thereof, I have computed the value of two miles of canal, which I suppose, if turned southwards a little below Menstrie Bridge, will carry it to Alloa: this is done upon a supposition of 40 l. an acre for the land, which I apprehend to be very valuable in that district, the rest of the dimensions and prices as per first supposition; this will cost the sum of 2408 l. This supposes a lock into Forth, but being nearly the same as that at Cambus, the only addition is in the canal.

Respecting the prices of land, I would be understood once for all, that I don't in these estimates by any means propose to fix a value upon it, as being an affair quite out of my province; but when different schemes are to be compared together, some value must be affixed to each of the component parts, in order to bring them to a comparison; for the cuts upon the valley of the Devon I suppose 201. per acre average price, though

I am very sensible that some of the grounds through which the cuts will pass, are more than ten times the value that others are: but as I apprehend the whole of the supposed cut from near Menstrie Bridge to Alloa, will pass through grounds valuable as the best in the Devon valley, the comparison would in no respect hold, unless an addition was made to those supposed for the Alloa cut.

I now come to the article of water, and for this purpose particularly observed the new mill at Titlibodie, which is situated upon the river Devon, and enjoys the whole stream thereof; its water is penned by the same dam, from whence the cut is proposed to be taken to Cambus Quay. This mill, when going at its common rate, requires the sluice to be drawn up 11 inches upon a breadth of 3 feet, there being then a depth of water upon the sole of 25 inches.

Having hence computed the quantity of water expended when the mill was going at this rate, it comes out to be 1180 cube feet per minute. A lock required to carry vessels of the fize above specified, will require to be 62 feet long, and 14 feet wide, whose area upon each foot in depth will be 868 feet; and supposing a lock to be of 6 feet pen, this will require 5206 cube feet to fill it, and the passage of each boat will require this quantity, unless two boats should meet together at a lock, one going up, and the other down, they then will both pass with one lock-sull; but as this does not always happen, I generally reckon upon a lock-full to each boat, the savings of water upon the aforesaid circumstance going in aid of the loss of water at the locks by leakage. Now the said circumstance going in aid of the loss of water at the locks by leakage. Now the sometimes of lock 5206 cube feet, being divided by 1180 cube feet expended at Tillibodie Mill per minute, gives 4 4 minutes for the time in which the said mill expends lock-full of water of 6 feet high.

Again, if we suppose 10 boats to pass in a day, that is, 5 up and 5 down, we may very well suppose that out of these 2 may meet at or within sight of the lock; and if so, a lock-full of water will be saved, which I esteem equal to the daily leakage of a well-smade lock; but however, to make an ample allowance for loss of water, not only by made lock; but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-leakage, but by evaporation and accidents in dry

By information of the miller, there is in summer scarcely half the above quantity of water in dry seasons, that is, they can scarcely go at that rate above 12 hours in 24; hence the navigation, circumstanced as beforementioned, will consume about Tr part of the water that now goes to the mills in dry seasons; or, dividing the whole quantity into 11 parts, the mills will get 10 and the navigation 1; but, upon my view, it appeared, that Tillibodie new dam was considerably leaky, insomuch that it is probable that in dry times as much water goes through the dam as goes to the mill; this will be the case if the leakage is only half the mill stream when working; for one being constant, and the going but for half time, they will be equivalent to each other; but, as it may be necessary to make some alterations in the dam of Tillibodie new mill, if this is rendered water-tight at the expence of the navigation, this mill will be a gainer and not a loser by the navigation. The Cambus mills, however, which are situated upon the same river, and take their water from the new mill of Tillibodie, and receive also the leakage from that dam, will not be compensated by that alteration; but as both the mills at Cambus work from one head of water, the loss to them both will be no greater than was estimated for Tillibodie mill singly; but the loss to neither of those sets of mills will take place, as to the lockage, except for such vessels as go down into the Firth; for all fuch vessels as deliver their cargo into the yard at the Cambus for shipping, which may be expected to be far the greatest part, will expend no more water from Tillibodie or Cambus mills.

It is true that, according to the different states of the tide, a perpendicular height might be wanted greater than six seet; but as it will be often less, I suppose the one may nearly balance the other.

It would render the affair of the mills intirely free from compensations if a stream could be turned into the *Devon*, that now goes into some other river, equivalent to what will supply the navigation, which, from my view in passing through the country near the head of the *Devon*, does not seem difficult to do.

However, upon the whole, it appears, that even in an extended view, the quantity of water that will be used by the navigation will bear but a small proportion to the currency of the river Devon, even in the driest seasons; and as a ground-work for a compensation, in case an equivalent quantity of water cannot be brought into the Devon, it appears that for every 5206 cube seet of water that is drawn out of each head, at such times when the respective mills can use the whole, I sum equal in value to 4.40 minutes

work of such respective mills will be payable to the tenant or occupier of such mill or mills, he continuing to pay the same rent as before.

Now, exclusive of Sauchie engine, which will be proportionably affected with the rest, there are only three heads of water that will be affected, viz. the Cambus mills, which are corn-mills; Tillibodie new mill, which is also a corn-mill; and the mill above Tillibodie Bridge, which is a lint-mill; which, in proportion to the value of its time, will be affected in much about the same manner.

I make no account of foakage, because this, after the canals are seasoned, will be very trifling, and the greatest part will return into the river above the principal mills.

Austhorpe, September 14, 1767.

J. SMEATON.

P. S. In regard to the scheme that has occurred to Messes. Mackett and Watt, since I was upon the place, of carrying a canal upon a dead level from Tillicoutery to a point opposite the schoolmaster's house at Alloa, sollowing the foot of the rising grounds the whole way, and which will be about 30 feet higher than the sea, proposing to continue the same from thence between banks across the stat ground to the waterside (which is not far), or making a cut through the stat grounds to the dead level termination of the canal, which plan would save locks and waste of water, I can only say, that, from my view of the country, I believe such a project practicable; but, as I have neither plans nor sections of the course that it would take, I am in no capacity to judge of the expence.

It is obvious that this canal would be defective in not suffering the vessels to pass into the Forth, and that either the banking across the valley, which would be a considerable height, or digging across it, which would be a considerable depth, would be a considerable article of expence; and that in any view of the assair, if a communication with the Forth is dispensed with, a considerable saving may be made, but I apprehend not above 1-3d, between carrying vessels to navigate the Forth, as above specified, and those the most curtailed that can any ways answer in point of quantity.

J. S.

WOFK

ESTIMATE for making a Navigation through the valley of the river Devon from	the
Cambus to Mellock Glen Foot, supposed chiefly by a canal.	

	£.	ž,	d.
To widening and deepening the old cut from the Cambus into Tillibodie new mill-dam, which,			
from the depth of the ground, I estimate as a new cut, the width at bottom being 16 feet,			
mean width at top 36 feet, mean depth 6 feet, at 3 d. per yard, will come to 47 l. 13 s. 4 d.			
per furlong, the length being 4½ furlongs,	214	10	
To 1 lock from the cut into the tidesway,	600		0
To 6,14 acres of land, if purchased at 20% per acre,	122	16	0
To 1 cart-bridge for communicating with the land cut,	40	0	0
To repairing Tillibodie new mill-dam, so as to render the same more nearly water-tight,	200		a
To extra cutting for passing-places, &c	27	0	8
To extra land for ditto,	15		
From Cambus Quay to Tillibadie Bridge,	1219	6	-
To clearing up and deepening the river from Tillibodie Dam, through the bridge, to the			
tail of the next cut,	50		0
To cutting 3 miles 1 furlong of entire cut, of the dimensions above specified, from Tillibodie			
Bridge to Sauchie new engine, that is, 25 furlongs, at 47 l. 13 s. 4d.	1191	13	
To 34,1 acre of land, if purchased at 201. at a medium,	682	0	0
To a road-bridge over the cut, answerable to Menstrie Bridge, with a stone arch,	80	0	0
To three cart-bridges to preserve the roads and communications between lands, from the			
above to Sauchie new engine,	120		0
To extra cutting for passing-places, &c	149	0	1
To extra land for ditto,	85.	0	
To digging a cut from Sauchie new engine to the elbow of the river near Tillicontery Burn			
Foot, being in length 1 mile or 8 furlongs, at 47 l. 131. 4 d. per furlong,	381	7	0
To 10,91 acres of land, at 201	218	4	0
To 2 cart-bridges over this cut,	80	0	0
To 3 locks upon this district, at 500 l. each,	1500	0	0
To extra cutting for passing-places, &c	48	0	0
To extra land for ditto,	. 27	0	0
To extra expence in cutting through the rising ground at the Coble Crook, -	100	0	0
From Tillibodie Bridge to the head of Sauchie Cut,	4712	4	0
		-	-

MIN TIME

	L.	1.	đ.
To raising a dam to pen about 7 feet water in the elbow of the river next above Sauci	bie		
old engine, near the foot of Tillicoutery Burn,	- 500	0	•
To embanking the flat ground adjacent to the river Devon, on the north fide from the fa	id in		
dam upwards, so as me be stood-proof, supposing it, me medium, to be for a mile length, 6 feet height, 6 feet top, and 24 feet base, this will contain 4400 yards, ramming	131 131		
and fodding or turking included, at 4 d.	- 73	7	
To 1 ½ acres of land, that will be cut and covered by this work,	- 30	-	o
To extra expence in securing the land near the foot of the dam, and in guarding the say	me		
from the effects of Tillicoutery Burn, suppose -	100	•	٥
Expence of continuing the navigation half a mile up the river Devon, from the head of	the		
Sauchie Cut to the tail of the cut near the bridge of Tillicoutery,	- 703	7	-
To widening or making a new cut past the bridge of Tillicontery, from the dam into the ri	iver		- 1
To widening or making a new cut part the bridge of I intentity, testing in length 2 furlor below the tunnel wherein the engine water crosses the same, being in length 2 furlor	ngs,		
	- 95	7	•
at 47 l. 135. 4 d. per furlong,  The land cut and covered will contain 2,73 acres, which, at 20 l. an acre, comes to	- 54	12	0
The land cut and covered will contain 2,73 deres, which	- 500	0	0
To a lock upon the said cut,  To a road-bridge over the said cut, answerable to Tillicontery Bridge,	- 80	0	
To a road-bridge over the laid cut, animelable to a mitter y	-		
The cut, &cc. to pass by Tillicoutery Bridge into Tillicoutery Dam, -	- 729	19	Ó
To cutting across the flat grounds from the first elbow of the river above Tillicoutery Da	m 10 	372	
Mellock Glen Foot, being in length 5 turlongs, at 471. 131. 4d.			0
The land cut and covered 7,5 acres, at 20% per acre,	- 150		0
To a lock upon the said canal,	- 500		
Two cart-bridges for preserving communications,			
To extra cutting for passing-places, &c.	- 33		
To extra land for ditto,			
	- 104	4 3	. 0
To carrying the navigation from Tillicoutery Dam to Mellock Glen Foot,	-		
' and the same the	valley of	the I	iver
SUMMARY of the Estimate for making Navigation through the	vancy or		
SUMMARY of the Estimate for making - I was supposed chiefly by Devon, from the Cambus to Mellock Foot, supposed chiefly by	canaus.		
Devon, nom the comment	- 1210	, 6	
From Cambus Quay to Tillibodie Bridge,			
To at this dea Reider to the head of Saucore Car, at	- 471	2 4	
engine at Sauchie, and near Tillicoutery Burn Foot,	- 70		7
through the river, to the root of the	- 72		9
The cut to pass by Tillicoutery Bridge into Tillicoutery Dam,	- 10	-	2 1
From Tillicountry Dam to Mellock Glen Foot.	10.	7	
From Tillicountry Diam to Internet or	ver 840	1 ·8	9
L'AFRE D	ACL OF		

[ 164 ]	£:	f,	đ.
Brought over -	8408	19	0
To 62 miles of towing-path, which, with towing-bridges, gates, siles, back drains, &c. is			
fusiposed to cost, 15% per mile,	97	10	0
Add to per cent. for unforeseen accidents and expences not included in the foregoing estimate,	8506 850	9 12	
	9357	1	_

ESTIMATE to shew the difference between keeping the river as much as possible from Tillibodie Dam to Sauchie new engine, and the entire canal before proposed.

porca.			
To clearing up and deepening Tillibodie Dam, through Tillibodie Bridge, to the tail of the		0	0
To outring from Willihadle Residee Into the Lint Mill Dam, being in length 4 furlongs,	and		
which pelling through deeper prounds than if carried upon a dead level, may be support	Hecr		
fire med death, which, with bottom and flopes as before, will contain 18164 yards,	and		
which being deeper, and partly under level of the river, fo as to require artificial drains	ige,		
T rickon at a d. per vard.	- 319	8	0
The ground cut and covered will be, at a medium, 100 feet wide, and therefore 4 fund	mgs		
will contain 6.06 acres, which, at 201, an acre, comes to	- 121	4	10
A lock upon ditto requiring drainage, and to be built higher than if upon a dead cut,	- 550	0	0
A cart-bridge over the cut for communication,	- 40	0	0
The work to pass the Lint Mill above Tillibedie Bridge, -	- 1080	12	101
To making a cut at the letter A, of a furlong of dimensions, as the former, will contain 4	.791		
yards, at 4 d.	- 75		0
The cut and cover will contain 1,51 acres, which, at 20%. comes to	- 30		-
A lock upon the cut as before,	- 550		
A cart-bridge over the lock for communication to the island,	- 15		
A dam to pen the water,	- 300	0	
Cut, &c. at the letter A,	÷ 974	19	0
To making a fimilar work at B, which will carry the navigation to Sauchie new engine,	- 97	4 19	
To 1 mile of cut, from Sauchie new engine to the elbow of the river near Tillicontery	- 38	. 7	0
Foot, as per former eltimate,	- 21		. 0
The land for ditto, as before,	- 8	-	
To two cart-bridges, as before,  To a lock from the cut into the river,	- 55		
To extra cutting for passing-places, &c. as before,	- 4		0
To extra land for ditto, as before,	- 2	7 0	0
Cut from Sanchie new engine to Tillicontery Burn Foot,	- 130	4 11	O

# SUMMARY of the foregoing estimate.

							£.	J.	d,
Cut from Tillibodie Bridge into Lin	Mill Dam	1.		-	-		1080	12	0
Cut from Tilnogate pringe into min	, 172100 25000	_			-	-	974	19	0
Cut, &c. at the letter A,					-	-	974	19	O
Ditto, at B,	illicouters R	unn Fest.		-		-	1304	11	0
Cut from Sauchie new engine to Ti	at tel			-		w	22	10	0
Increase of hawling track 14 mile,	, ac 13 11								***
From Tillibedie Dam to Sauchie Ci	. bu leaan	ine w m	uch as no	lible the cou	rse of the r	iver,	4357	11	0
From Tillibedie Dam to Saucme Ci	er, by Recep	mig an in	Man on La	-	-	-	435	14	
Contingencies, at 10 per cent.	•	-							
							4793	5	0
				f. 47	12 4 0				
By an entire canal, as before,	_				71 4 0				
Contingencies, at 10 per cent.		-					5183	8	0
	16 A - 2	. mauicat	ion.		-		390	3	0
Difference of expence in favour of	of the river	Hankar	TOTAL						

# ESTIMATE for continuing the navigation, by Canal, to or near Alloa.

If, instead of dropping the cut into the river just above Tillebodie Bridge, the level be preserved from the Coble Crock, and turned from near Menstrie Bridge towards Alloa, the increase of distance, according to plan, will be about 2 miles. f. s. d.

ing to plan, will be about 2 miles.						£*	3.	44.4
					de	762	13	0
To 2 miles of cut, at 47 /. 13 s. 4 d.	-	•			-	872	16	O
To 21,82 acres of land, at 40/. per acre,					-	160	0	9
Suppose 2 road-bridges, \$80%	-	-		_		160	0	0
To 4 cart-bridges, = 40%	-	-		_	-	30	0	0
To 2 miles of hawling track, at 15%.	-	•			-	95	0	0
To extra cutting for passing-places, &c.	7				-	109	0	0
To extra land for ditto,		-	100				<u> </u>	
TO CYTIA TRIPE						2189	9	0
					-	219	0	0
Ten per cent. for unforeseen events, &c.	-	-	•					
Ten per cent. for different					-	2408	9	0
Addition, to carry the cut to Allea,	-	7	•					
Addition, to carry the cut to and								

J. SMEATON-

Austborpe, September 14, 1767.

Lord CATHCART's Queries of the 11th of September, 1767.

To Mr. SMEATON, from Lord CATHCART, September 11, 1767.

In winter the freshes and quantities of ice are so great, that it is difficult for ships to lie in the Forth; they are obliged in that season to shelter themselves in what is called the Pow of Alloa; they cannot go up to Cambus, nor can boats come down, which would prevent a constant intercourse between the Devon collieries and the ships in the Forth, supposing the navigation to be made partly in the Devon, and partly in cuts from Tillicoutery to Cambus, where it joins the Forth.

There is another method which would be certain and constant \*, except when the canal was frozen, and is as follows: suppose Lord Cathcart's aqueduct were to be widened to the proper size, from the pipes at Tillicontery to the new engine at Sauchie, and from thence carried on upon the same level to the west end of the town of Alloa, it would finish upon a bank about 15 feet higher than the pier of Alloa, and about 300 yards distant from it; from this dead water canal a branch may be carried off, which will be very short, and which will terminate equally on a bank near the Forth, a little below the mouth of the Devon, from both which banks the coals may be conveyed in waggons to the sides of the ships at Alloa, or boats at Cambus, which come down the Forth from the upper parts of the river.

In this plan there are the following advantages:

There will be no locks; there will be no waste of water, which will be particularly agreeable to some proprietors principally concerned.

The boats may be contracted in width and increased in length, and may be very flat, and consequently the canal much shallower and narrower, than if it were to carry boats fit to navigate the *Devon* or *Forth*.

And for these reasons it is supposed the navigation may be executed cheaper, and with more certainty than in any other method, and may in the same manner be carried up the

river, as far as proprietors please, on the north bank, although on the upper part there will be a necessity to have some locks, as it must be on a higher level than the under.

Query 1st. Were such a canal to be executed, what would be the proper dimensions of it, and of the boats, and what would be their burthen?

Query 2d. Would there be any difficulty in carrying such a canal over rough ground about Cobble Brock, or any danger that it should penetrate into the waste of the Alloa coal over which it must pass, or that by any little falling in of that waste, which now and then may happen, the canal may be lost?

N. B. The waste is 20 sathom below the surface, and there are collieries which do not lie deeper, and are wrought under the sea without inconveniency; but as this danger struck the proprietor, it is thought proper to ask the question.

Query 3d. How much per mile ought such a canal at an average to cost?

# ANSWER to Lord CATHCART'S Queries of the 11th of September, 1767.

To query ist. THE boats proper in my opinion for a small canal, is not to make them of extraordinary length, but to make them go in pairs; the sternmost boat serving as a rudder to the headmost boat, which not only gives them a very great advantage in turning, but by keeping them short renders them much stiffer, and consequently subject to less wear and tear.

This method is practifed in all the rivers and canals communicating with the great levels of the fens of Lincolnshire, Cambridgeshire, Norfolk, &c. where they sometimes go in gangs of four, five, six, sometimes seven, in a string, and where the second boat, string the first, is followed by all the rest in the same curve; their burthen is from 15 tons to 5.

I cannot, however, recommend to many of them for your purpose, as your voyages will be shorter, the returns quicker, will be managed with sewer men and horses, and in a very narrow canal more easily directed.

The

<sup>\*</sup> Since writing, I have been informed, that the water drawn from the pits, with which the canal before mentioned would be filled, never freezes.

The dimensions I would recommend for your use are as follows:

The head boat Extream length, - - - 38 0 Burthen 12 tons.

Draught of water loaded, - 2 6

Extream length, - - - 36 0

Extream breadth, - - - 9 0

Burthen 12 tons.

Extream breadth, - - - 36 0

Draught of water loaded, - 2 4

These two boats will be drawn with one horse from 2 to  $2\frac{1}{2}$  miles per hour, and will be managed by one man on board.

A canal proper for such boats, so as to suffer them to draw freely, should be 12 sees bottom, with 3 feet depth of water; the width of the water-line will vary according to the batters; but supposing those at a medium to be 3 to 5, and the surface at a medium 2 feet within soil, the ordinary expence per mile, at 3d. per yard, will be 242l. and the quantities of ground, including cut and cover per mile, will be about 6 acres English measure.

Where great hollows are to be filled, or hills to be cut, the extra expences thereof are to be further allowed, as all the charges of aqueduct and common bridges, tunnels, backdrains, towing-paths, &c. to be added; also allowance made for passing-places, turning-places, &c. which may in a great measure be judged of by my report and estimate already delivered on the subject of the river Devon, but cannot be more particular at present, for want of plans, sections, and time.

To query 2d. I don't apprehend any extraordinary difficulty with the rough ground about Cobble Crook, more than what happens in like cases. As to danger from the falling in of the old wastes of the Alloa coal, I don't apprehend they can affect the canal, or the canal affect them, unless there happens a fail immediately under the canal which seaches the surface; in this case, the water of the canal will undoubtedly make its way down into the waste; but if steps are constructed at proper places, as is done in the Duke of Bringewater's canals, no great quantity can go down, and the breach may be repaired so as to be water-tight as at first; but if wastes of collieries are supported like those which are worked under the sea, and are not used to fall in so far as the surface, I can see no reason for this apprehension.

Austborpe, 8th October, 1767.

J. SMEATON.

P.S. I don't know that it is a property of coal-pit water not to freeze: it is certain that the water from all mines comes out of the earth at about the forty-eighth degree of FARENHEIT's scale of heat, it must therefore remain unfrozen till by the superior cold of the external air, and surface of the earth, it is reduced to thirty-two degrees of the same scale. If it has any property by which it remains unfrozen, after it's heat is reduced below that degree, it is a peculiarity I am unacquainted with.

MEMORIAL and QUERIES relative to Mr. SMEATON's Report of the Navigation of the Devon, of the 14th of September, 1767; from Lord Cathcart, the 14th of March, 1768.

MR. SMEATON, in his report of the Devon Navigation, dated September the 14th, 1767, lays down the following proposition.

That the navigation may be carried up from the Forth at Cambus to old Sauchie, by two methods, which he describes and estimates, by making a canal the whole way from Tillibodie Bridge to Sauchie, or by making a cut from Tillibodie Bridge to Minstrie Lint Mill Dam, and making use of the bed of the river from thence to old Sauchie. Mill Dam, and making use of the bed of the navigation from the Forth to Mr. Smeaton estimates the expence of this part of the navigation from the Forth to Sauchie in the first manner, that is, using the river as little as possible, at 51831. and in Sauchie in the first manner, that is, using the river as much as possible, at 47931. and though the the second, that is, using the river as much as possible, at 47931. and though the former, according to his estimate, will cost 3901. more than the latter, he prefers and former, according to his estimate, will cost 3901. more than the latter, he prefers and recommends it, for the following reasons, viz. because the distance will be shortened in 6½ miles, and because the works will be in less hazard from floods, and will require less repair.

The following considerations, in favour of the second method, are submitted to Mr. Smeaton, who, when he made his report, was under the disadvantage of being deprived of papers and memorandums relative to the levels, and other circumstances of the Devon.

1st. There is already  $4\frac{1}{2}$  feet of water in the Devon, from the Lint Mill as far up as Coble Brook Ford, so that the work at A, in Mr. SMEATON'S Plan, estimated at You. I.

being in water 9 seet deep, cannot be necessary, the price of it ought to be added to the balance in favour of the second method, and will raise it from 3901. to 14651. which is an object.

little below Sauchie new engine, there is a rife of no more than 3 feet 2 inches; at Celle Crook there is a foundation of rock, with rocky and steep banks on each side, and a very good quarry close to it, so that there seems no reason to believe a dam of 3 feet 2 inches high, and a lock of that rife, can possibly cost a sum, upon any principle of Mr. Smeaton's other calculations equal, or near equal to 9751. but it may be proper to leave that article as it stands, because if the people of Alloa are cut off from Alloa, by the ford being destroyed by the dam, there will be a necessity to build a bridge over the Deven, probably at Sauchie, as there is a good soundation and a quarry at hand, which will cost 2001. if so, the expence of the second method will remain 38181.

3dly. If the first method is used, the expenditure of water from the Tillicontery Dam, which supplies Sauchie engine, will be increased by the consumption of the Sauchie and Collyland coals, which in the second method would embark in the river above the Coble Crook Dam, and would waste none of the water belonging to the Tillicontery Dam; and it must be remembered that the Sauchie engine can on no account give up any water which it has or may have occasion for, and has at present a right to.

4thly. The greatest difficulty attending works now to be carried on in Scotland, will be the want of labourers. The execution of the second method will not require above one-sixth part of the labourers the first would require, because the digging is as  $\frac{1}{2}$  to 3, and the lockage as  $3\frac{1}{2}$  to 20.

5thly. As the Lint Mill and Tillibodie Mill Dams have been proof against the greatest sloods, it may be presumed that the Coble Crook work, which is better placed, and will be better, will be equally safe, and will be a security to the works below.

Query 1st. Upon the whole of these considerations, does Mr. SMEATON admit the deduction of his work at A, and it's expence 9751. Does he recommend the canal from Sauchie to Tillibodie Bridge, or the river from Sauchie to the Lint Mill; and if the latter, would he place the lock at Coble Crook, or at any situation above it, in which case the Coble Crook Ford must be deepened?

Proposition 2d. Mr. SMEATON proposes to carry up the navigation from Sauchie to Tillicoutery Burn Foot by canal, to raise the river by a dam to supply that canal, to cross the river and lock up into a cut on the north side and on the level of Tillicoutery Dam, to repass the river above Tillicoutery Dam, and lock up into a cut on the level of the tail-race of the Rack Mill, and in that cut to proceed to Mellock, and for these operations he makes the following charge:

	$f_{a^{+}}$	3.	d,	
From Sauchie new engine to Tillicontery Burn Foot,	1304	11	0	
From thence, through the river, to the next cut,	703	7	0	
Cut into Tillicontery Dam,	729	19	0	
Cut from thence to Mellock Foot,	1044	3	0	
Towing Path, m 15% per mile, for 2½ miles,	37	10	a.	
	£. 3819	Id	0	

It is submitted to Mr. SMEATON, whether the following method would not be preferable, for the following reasons, viz. To enlarge the Sauchie aqueduct to the size of a canal from the New Engine across the road leading to Tillicoutery Bridge, to carry it either on the same level as sar as Mellock, being 2 miles and a half, and there raise it by a lock to a level of the tail-race of the Back Mill, and continue it from thence the space of 1 mile surther to the tail-race of the said mill, or by placing the lock nearer space of 1 mile surther to the tail-race of the said mill, or by placing the lock nearer space of 1 mile surther to the tail-race of the said mill, as may be thought most convenient.

the works at Tillicoutery Burn Foot, the most precarious and expensive, in point of repairs, in the whole navigation, will be faved, and the price of it being 7031. will probably more than answer the extra expense of carrying a canal along the fouth bank probably more than answer the extra expense of carrying a canal along the fouth bank of the river, betwixt Tillicoutery Bridge and Tillicoutery Dam, where the ground is more narrow and difficult, as well as the additional length of canal beyond Mr. Smeaton's calculation, amounting to 6 furlongs, which, it is apprehended, will require less calculation, amounting to 6 furlongs, which, it is proposed to run through expense in digging and in land than the shorter place, which is proposed to run through ground much more valuable, and to be cut much deeper within soil, especially betwixt sauchie and Tillicoutery Burn.

2d'. Because by keeping the canal 20 seet above the level of the river at Hennies Burn, it may be, with the same expense, communicated by locks at that point, as if the lockage had been dispersed along the whole course of it; and if either money or hands

hands should fall short, the execution of these 20 feet of lockage might be postponed, and an immediate communication opened, for the time being, betwixt boats coming up the Devon, as far as Sauchie from the Forth, and boats coming down from the Rack Mill to Sauchie, till the junction is compleased by locks.

Jd. Because, by carrying up the navigation 1 mile beyond Mellock, no additional lockage will be incurred, as the lock necessary is marked in Mr. Smeaton's plan, and the expence included in his estimate; so that the additional expence will be no more than the digging, land-bridges, and towing-path of 1 mile, amounting, according to Mr. Smeaton's estimate, to 7691, and the benefit of water carriage will be communicated to Dollar and the country above it, as there is now a bridge at the Rack Mill, and to the Blairngon Colliery, to which a road for the carriage of coal may easily be made; and it is supposed that the produce of that colliery, whether carried to the sea or to the north country, would go down the Devon, which would both increase it's produce and raise it's tolls.

Query 2d. Is Mr. Smeaton of opinion, that the navigation ought to be carried up to Mellock in the manner above described, keeping the south side of the water the whole way, and that the expence will not exceed the above estimate of 38191. 105.? That it ought also to be carried up to the Rack Mill? and that the additional expence will not exceed 7691.—in all 45881. 105.? To which supposing 38181. to be added, for the space betwixt Cambus and the Sauchie, the two sums will make 84061. 105. and with 8431. 105. for extraordinaries, the whole expence of the navigation from Cambus to the Rack Mill, for boats drawing 3 feet water, will amount to 92501. according to the principles of Mr. Smeaton's estimate.

Query 3d. As the boats described by Mr. SMEATON, drawing 3 feet water, are only fit to go down the Forth, as far as Carron, with which the Devon, as both their produce in coal cannot have much intercourse, it is desirable that a foot of additional depth should be given to the works below Sauchie, in order that they may be passable for boats drawing 4 feet water,  $13\frac{1}{2}$  feet wide, 42 feet long, and carrying 25 tons; such boats being constructed in the Clyde, for the navigation of the highland seas, and therefore supposed fit to go to Leith, and in summer to the north country. Query, What additional expence would this alteration cost? It is supposed, that if a foot were to be added to the Lint Mill and Tillibodie Mill Dams, the river would still be within soil, and would require no banking, and, if so, that a foot more water would

î Ît .1 10 2' -

be thrown into the two cuts without any farther expence for extra digging, and that in the river there is a sufficient depth.

Query 4th. What would be the expence per mile of deepening the canal 1 foot between Sauchie and the Rack Mill?

Query 5th. The ground being favourable for cutting a canal, on a dead level, from the Lint Dam to Stirling Bridge, where it might be communicated, by a lock or locks of 11 feet fall, with the Forth, it would be proper to include this circumstance in the act of Parliament, because not only all the coals for the north country sale would be conveyed by it to Stirling Bridge, but also the Upper Forth boats coming to the Devon for coals would lock up at Stirling Bridge, rather than Cambus, as they would fave near 12 miles each trip; the expenditure of water would be diminished rather than increased, because the lockage is not computed at more than one lock-full per day. The coals for the north country and for Stirling would waste no water, which they must do were they to go down the Devon and up the Forth, and the boats coming and going from and to Craig forth would waste the same water, whether they entered the canal at Stirling Bridge or the Devon at Cambus. Mr. SMEATON estimates 2 miles of canal between Mensirie Bridge and Ailea, at 24001. and the lockage from the level of the former into the Ferth of the latter, at 11001.—in all, 35001. Query, The height being the fame, and the distance one third greater, is not 4700 l. an adequate price for the branch from the Lint Mill Dam to Stirling Bridge, being 3 miles in length, and for the lockage into the Forth? viz. together with the former fum of 92501. would make in all 139501. for the navigation of the Devon, and for the branch to Stirling.

#### PERTH BRIDGE.

# MEMORIAL for Mr. SMEATON.

August, 1763.

THE Justices of Peace for the county of Perth, at their quarter sessions in May last, having entered into several resolutions to promote a scheme for building a bridge across Tay, at or near Perth, did, among others, appoint a committee of their number to meet with and consult Mr. SMEATON on this subject.

These gentlemen now take this opportunity of applying to Mr. SMEATON, that he will visit and inspect the river at and near the town of Perth, and report to them the proper place for erecting such a bridge, paying alwise a particular attention to the safety of the town of Perth and the adjacent grounds, as well as the bridge.

He will be pleased, at the same time, to consider how far a stable bridge, of any other materials than stone, can be constructed, so as to answer all the requisite purposes of carriages, &c. and be made more properly adapted to the situation and rapidity of the river and safety of the town.

As Mr. Smeaton will satisfy himself as to the measures of the breadth of the river at the different places, it is only necessary to observe, that the land-floods often swell the river, with great rapidity, 14 feet higher than the water is in summer, and that the stream-tides flow to the height of 8 feet, or thereby, opposite to the North Key, where the former bridge was built, and that the bed of the river is generally hard gravel.

If Mr. Smeaton should approve of the scheme, and determine on the situation, it will be proper that, with conveniency, he make a plan of such bridge as he shall judge most eligible; for which plan, and his trouble in visiting the river, the committee will properly gratify him.

The REPORT of John Smeaton, Engineer, concerning the practicability of building a bridge over the river Tay, at Perth, in answer to a memorial thereupon addressed to his consideration by the committee of Justices, bearing date August, 1763.

HAVING, pursuant to my instructions contained in the said memorial, examined the soundings of the river Tay, at and near the town of Perth, in the month of August last, as well as other circumstances relative thereto, I am of opinion as sollows:

1st. That from the rapidity of the river, and the quantity of ice, said to come down the same in winter, that though a bridge may be built of timber sufficient to answer the purpose for a number of years, yet, to give the same the necessary degree of stability, will, in it's first erection, be near as expensive as if built with stone, and, from the perishableness of the materials, be subject, in the course of a sew years, to great and expensive repairs; and withal considering that this is a part of the country where good workable and durable stone is cheap, and good oak timber dear, I can by no means recommend a bridge of any other materials than of stone.

2d. I am of opinion, that it is practicable to build a durable and useful stone bridge at or near the town of *Perth*, and without any danger or hazard to the town likely to arise therefrom, provided it be constructed with a sufficiency of water-way.

3d. I am of opinion that two of the most proper places for the situation of a stone bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge was bridge is either in a right line with the Town Street, nearly where the old \* bridge was bridge wa

4th. Of these two places, I preser the latter, on account of less difficulty and less expence; for though the river is wider at the latter situation than at the former; yet, as the depth is considerably less, the expence and hazard of making coffer-dams for laying the soundation of the piers, will be very considerably greater opposite the town than at the soundation of the piers, will be very considerably greater opposite the foundation will the North Inch; and the expence of making dams and clearing the soundation will

be further enhanced by the remainder of the old piers, all or most of whose foundations probably remain in the river.

5th. In consequence of this preference, I have made a design for a stone bridge to be erected from the tenter at the North Inch to the opposite shore, which accompanies this report, and have also annexed an estimate of the expence; the width of the river here I make to be about 653 feet.

6th. It is to be remarked, that it appeared to me, from founding, that the bed of the river was every where a firm gravel, sufficient to support the weight of such a bridge as I have proposed; but from information I learnt, that, in digging near the river, there is every where a stratum of sandy clay, laying about 4 feet under the bed of the river, and about 4 feet thick: now, as some excavation in the bed of the river will be necessary, this will reduce the upper crust of gravel so thin, that the stratum of fandy clay, being of a yielding nature, the bridge cannot with fafety be trufted upon it without piling, nor even with piling so securely in nor can it be done at so small an expence as by carrying the foundation down to the surface of the under-bed of gravel, which is faid to reach to an unknown depth. For these reasons, I have supposed the foundation of the bridge to be laid 8 feet under the bottom of the deepest part of the river, where the bridge is proposed to be fixed, and have estimated the expence accordingly; but if it should turn out, on boring or digging, that the upper stratum of gravel is considerably thicker than here supposed, or that no such stratum of sandy clay subsists at this place, then a considerable expence will be saved, the foundation being here supposed to be laid 10 feet under the surface of the river at low water in dry seasons. On this account, I would advise the foundations to be tried before any thing definitive be determined.

7th. It is to be further remarked, that the prices in the following estimate are such as are usual for such kind of work in this part of the kingdom, and such as I apprehend it may be done for at Perth; but, for surther satisfaction, if the committee please to order my estimate to be drawn out, with the quantities there inserted, without the prices, they will have an opportunity of having the sentiments of the workmen of the country thereupon, by causing them to fill up the same; only regarding the coffer-dams, as the method therein proposed cannot be explained without models, nor indeed successfully practised but by a person experienced therein; their sense thereupon will be best had, by stating the internal circumference of the dams, and that they are, at a medium, to pen out 6 seet water: the committee will thereby come at the cost thereof in such method as the workmen themselves would propose; but, as the method is put in daily practice

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practice here, the committee may depend on it's being practicable, and at the prices stated, unless there is a material difference in the value of timber and labour here and at Perth.

ESTIMATE for erecting I Stone Bridge over the river Tay, at Perth, from the Tender at the North Inch to the opposite shore; to have 7 principal arches, extending 605 feet 9 inches, and in the whole length 893 feet; to be 22 feet in the clear, within the parapets, and to have a walking path on the south side of 4 feet wide.

By John Smeaton.

#### COFFER DAMS.

THERE being, according to my information, Infratum of hard gravel at the depth of 8 feet below the bed of the river, I propose to sound the piers immediately thereupon, without piles or grating; and in order to come at this soundation, as the river will not in it's low state be above 2 feet deep of water, and does not rise at ordinary spring tides more than 8 feet above this mark, and at neap tides little worth regarding, I reckon that a dam, capable of holding out the water 4 feet above it's low state, will enable the workmen to work nine or ten days successively between each spring tide; and I apprehend a dam of this height will not only be constructed at a much less expence, but be less subject to hazard, than if raised so as to pen out the spring tides; this dam to have a sluiject to hazard, the water in and out, as occasion shall require; and, for the more safe and ready excavation of the matter, I propose the dam to be placed at a medium safe and ready excavation of the pier, and to be of an elliptical figure, the better to resist the tides and sloods.

	£-	- Je	d.	
anah.	13	0	Q	
The second secon	135	16	0	
To 122 cube feet of timber, in itring pieces, for 127	:8	6	•	
at 3 s.  To extra work, in making a fluice for letting the water in and out,	2	10	0	
	-	•	£. 169 12° .	0
To timber work in one coffer dam,				

• In the estimate delivered in, this number was by mistake called 2 instead of 12s, and the dependent sums being less accordingly, made the articles of the coffer dams be 7241. 2s. instead of 7261. 2s.

YOL. I.

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Dear	ght for	verds.		160 12	~,
		Q.		109 12	0
To pile shoes, for 26 gage piles, at 1 s. each,	6 2	,			
To plank pile shoeing, 245 running, at 6 d.	2 10				
To ar holes for the string pieces, at 21, each,	2 0	0			
To extra iron-work about the shuttle, and contingencies,					
	-	-		11 18	
To iron-work about one coffer dam,		en ,		181 10	1
A coffer dam complete,  The materials for the first pier is supposed to be of half value toward each.					
succeeding pier, which will therefore be No. 6. at 90 l. 15 s. 3 d. each,	~	-		544 11	1 6
fucceeding pier, which will therefore				726 :	2 (
Coffer dams for the whole			-		
Excavation and drainage.					
	18				
To excavation of the matter 722 yards, at 6d. comes to, each pier,	10				
To excavation of the matter, supposed equal to 50 days, at 20s. per day,	50	0 0			
per pict,	20				
To excavation and drainage of 6 piers, the 2 abutment piers, and foun-	68	1 0	+		
dation for the wing walls, being supposed equivalent to 2 piers, the					
whole will be equivalent to piers, at 68 l. 1 s. each,				544	8
Whole will be equivalent to a prost, as		4			
Masonry in the piers and abutments below the springing of	of the	arch	ies.		
To 1080 feet superficial of ashler in each pier below water, at 7 d.	31.	10 0			
To 1080 feet superficial of aimer in each pier beton	39	4	<b>)</b> .		
To 1176 ditto above water, at 8 d.  The whole pier, in folid, contains 467 cube yards, including labour, car-					
The whole pier, in folid, comains 407 costs justified joints, and all materials, at riage, tarras mortar 6 inches in the outfide joints, and all materials, at					
51. per yard,	116	15 1			
N.B. The ashler being at least 20 inches bed, and cubed into the solid, at					
5. per yard, is supposed to pay for the tarras mortar and extra labour					
in setting thereof.					
To capping the pier with solid blocks jointed between the springer					
Armen 600 cube feet, at 6 d	15				
The compine the ends of the piers 148 feet superheial, at 8 d.	4	1.8	8		
To 6 piers, and abutment piers, each reckoned as a pier, that is 140. 6,					
	1659	1	4		12.1
The walking in the west land stool to bring it up to the springers, to be at					
a modium a feet thick, containing 400 cube yards, at 55.	122	10	0		
To hammer-dreffing that part of the wall that comes in view below the					
which containing 666 feet superficial, at 12,	4	3	3		
To working the plinth, being before reckoned as folid, containing 990		-	6		
feet funerficial, at a d.	12	/			
To 78 cube yards of masonry in the east land stool, to bring it up to the	10	10	0		
height of the springers, at Cs	•9	.0			
To fetting under the west abutment arch to prevent the water from affect-	22	12	0		
ing the foundations, 1353 feet, at 4d.				1840	3 1
Masonry in the piers and abutments below the springing of the arches,					
					,

# Centering for the arches.

Centering for the arches.			
To timber in one rib, 416 cube feet, and for 6 ribs - 2496 cube feet.  To timber in 30 bearing piles, and 5 capt-trees for supporting the ribs, - 750  To stays and bracings between the ribs to keep them upright 75  To covering for the centers in square scantlings - 525  To additional work to make the centers fit the larger arches, 188  L. s. d.	£. s.	d.	
To timber in a center compleat, at 31. per foot, - 4034 605 2 0			
To ironwork in the fix ribs, 1852lb. at 5 d £. 38 11 8  To ditto in pile-shoes and hoops, 662lb. at 5 d. 13 15 10  To spikes, nails, and other contingent articles, - 5 0 0			
To ironwork for one center, - 57 7 6			
	662	9 6	
To one center compleat,  To a fet of piles and cap-pieces ready prepared for driving in the second arch before the first			
To a fet of piles and cap-pieces ready prepared to the fixed as struts between the piers of	75	0 0	
To 5 booms, containing 375 feet of timber, at 23. to be first, and putting up in the second, the second arch, while the center is taking down from the first, and setting up the center six	37	10 0	
	907	13 0	
the state of the s	46	17 6	
the days and putting up the booms ave thires, at	20	0 0	
To taking down and putting up.  To centering for one of the small arches, at 1 /. per square,  To taking down, removing, and setting-up ditto in the other arch,	5	0 0	
	1754	10 0	
Centering for the bridge, compleat,			
Masonry in the superstructure.			
To 15850 feet superficial in the sossite of the main arches, being three seet thick, set in	1320	16 8	
place, and mortar included, at 20d.	100	0 0	
To 2000 feet superficial in the some of the arches solid, 6 feet high, containing 473 cube yards,	118	5	
at 5 s.  To cube majoury in the spandril walls, abutments, and wing walls, from the top of the piers  To cube majoury in the spandril walls, abutments, and wing walls, from the top of the piers	-11		
To cube masonry in the spandril wans, abutine responses to the top of the cordon, containing 3776 yards, at 51.  to the top of the cordon, containing 3776 yards, at 51.	944		0
to the top of the cordon, containing joint and the cordon, tontaining joint and the cordon			
The paramet 11800 feet superficial on	169		0
Asia mortar, and letting unto, as one	,		
* MACHETIAL WILLIAM	_ 300	5 7	4
4 11 F		, c	0
	3-7		-
A a 2			

	L.	1,	d.
Brought forwards -	3271		
To 2160 feet superficial in the 12 eyes, and 640 feet in the terminating pillars, in the whole			
2800 feet superficial of circular work, (being before included in the solid) at 6d.	70	a	0
The walking-path, being 4 feet wide, contains 3641 feet superficial, stone, working, and			•
laying, at 7 d.	106	12	0
Masonry in the superstructure,	347	17	0
			-
GRAVEL.			
To 10948 cube yards of gravel to fit up the spandrils and wing walls, and form the road, at			
9d. per yard,	410	1.1	0.
N. B. No part of the road is considered except what falls within the walls of the bridge.	7.7		
and the fact of the found to be a fact of the fact of			-
CONTINGENCIES.			
CONTINUE NO LEGI			
To piling engines, pumps, and other utenfils, supervisal, unforeseen accidents, and expences,	1000	0	0
			-
ABSTRACT.			
To coffer dams,	726	2	0
Excavation and drainage,	544	8	0
Masonry in the piers and abutments below the springing of the arches,	1840	3	1
Centering for the arches,	1754	10	0
Masonry in the superstructure,	3447	17	0
Gravelling the bridge,	410	11	0
Contingencies,	1000		
Total -	9723	11	1

N. B. In the batterdeaus and centers there will remain at least 5763 cube feet of timber, which, if sold for 9 d. = foot cubic, will amount to 2141. 21. 3 d. besides ironwork, engines, and utenfils, which, it is presumed, will be sufficient to make the road to and from the bridge,

The prices in the preceding estimate includes all labour, carriage, mortar, and setting-up in place, unless otherways particularly expressed.

EXTRACT Minutes of the Trustees for building a Bridge over the Tay, at Perth.

AT Perth, the 26th day of September, 1765 years, at a meeting of the trustees for building bridge over Tay, at Perth, sour letters from Mr. SMEATON to the Earl of Kinnoul, dated 12th of July and 1st of August, 1764, and 9th of April and 3d of May, 1765, being read, upon consideration thereof, and of the sums subscribed in free gift towards building the bridge, it is the opinion of this meeting:

1st. That the work shall be begun next year, by raising an experimental pier, under the direction of Mr. Smeaton, as proposed by him, and that the materials necessary for raising such a pier be prepared in due time.

2d. That Mr. John Adam, architect, is a proper person to be employed in preparing such materials.

3d. That Mr. ADAM be defired and authorifed to open, and try, proper and convenient quarries for that purpose.

4th. That a committee be appointed to confer and treat with Mr. ADAM, and to receive proposals from him concerning such materials, which proposals he is desired to lay before the Committee.

5th. That the said Committee shall, from time to time, as they shall think proper, report their proceedings to a meeting of the trustees, and that the clerk shall call a meeting for that purpose, whenever the said committee, or any two of them, shall defire it.

6th. That the Earl of Kinnoul; Lord Gray; Mr. Crawford, of Errol; Mr. Greene, of Ralgovan; Sheriff Swinton; Mr. Belches; Provost Simpson; Mr. Olderner, of Rossie; Mr. Craige, of Dumbarney; Messer. Robertson, elder and younger, of Tullibeltan; Mr. Richardson; Mr. Mercer; Mr. Wood, Dean of Guild Sande-of Tullibeltan; Mr. Richardson; Mr. Mercer; Mr. Wood, Baillie Marshall; Man; Baillie Fyfe; Mr. William Sandeman; Baillie Ramsay; Baillie Marshall; Baillie Faickney; Mr. Thomas Anderson, and other Trustees that shall please to attend, shall be of the said Committee; and that sive shall be a quorum; and that Mr. Mercer shall be convener.

7th. That the clerk shall transmit extracts of the foregoing resolutions to Mr. SMEATON and Mr. ADAM. Extracted from off the record of the minutes of the faid Trustees, by

PAT. MILLER, Clerk.

EXTRACT Minutes of the Commissioners for the Bridge over the Tay, at Perth, in relation to Mr. JOHN GWINN trying the foundation, &c. and his report, 1766.

AT Perth, the 27th day of February, one thousand seven hundred and sixty-six years, sederunt, the Earl of Kinnoul, Provost Simpson, Mr. Mercer, Mr. Wood, Baillie MARSHALL, Mr. WILLIAM SANDEMAN, Mr. DUNCAN, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, and Mr. SAMUEL SAMPSON, commissioners appointed by Act of Parliament for building a bridge over the river Tay, at Perth.

# The Earl of KINNOUL chosen Præses.

The committee appointed by the commissioners the 26th day of September last, gave in the following report of their proceedings, to wit,

At Perth, the 20th day of February, faiery ditto, and fixty years, at a meeting of the committee of the commissioners for the bridge over the Tay, at Perth, sederunt, the Earl of Kinnoul, Provost Simpson, Mr. Mercer, Mr. Wood, Mr. James DUNCAN, Mr. THOMAS MARSHALL, Mr. ALEXANDER FAICKNEY, Mr. THOMAS Anderson, the Earl of Kinnoul Præses.

The committee having communed with Mr. Gwin, the person recommended and fent by Mr. SMEATON, direct him to continue boring at that place, which Mr. SMEA-TON pointed out to be the properest place for the bridge, according to the opinion he had formed when he surveyed the river, until he has discovered, as well as he is able, the metals that are to be found in the bed of the river, the whole way across the same, and that he would likewise bore across the river opposite the town-house, and in any other part he shall think proper to try; and that he will report to the commissoners, at their meeting the 27th instant, what place he in his judgment, upon full confideration of all circumstances, and upon the best information he can get of the state

flate of the river at the different parts in the time of speat; thinks the most eligible for erecting the bridge, with his reasons for such opinion; and that he will also report the particular state of the metals as he shall find them at the different places by his boring, and that he shall likewise include in the said report a particular of the materials he shall think necessary in his branch of business for erecting the experimental pier this fummer, always understanding that Mr. SMEATON is willing that such pier be erected in the most difficult part of the river, and also what number of hands it will be necessary for him to employ in his branch, in order to prepare every thing for erecting such pier as early this spring as the state of the river will admit; and Mr. SMEATON'S other engagements will allow him to come here for that purpose, distinguishing what men he thinks it absolutely necessary to bring with him, and the terms upon which such men may be engaged, and what number of hands he would have engaged here; and laftly, that Mr. Gwin will acquaint the commissioners at what time he proposes to return, to begin these preparations.

The committee order the clerk to communicate to Mr. Gwin Mr. Smeaton's plan, estimate, and report anent the bridge, with his letters to the Earl of KINNOUL, and also to the clerk there anent.

The committee empower Mr. MILLER, their treasurer, to defray the expence of quarrying the stones, and to pay Mr. Gwin such sums as shall be necessary for preparing the works which he is engaged in, and for providing materials.

The committee direct the treasurer to draw upon Mr. Andrew Drummond for fuch fums as he shall inform him, from time to time, are in his hands, and to remit the same to the bank at Edinburgh, with the profits of the exchange.

The committee direct the treasurer to remit to the bank such sums as shall come into his hands, in the most proper manner.

The committee appoint that these their proceedings to be reported to the next meet-KINNOUL, P. ing of the commissioners.

(Signed)

The clerk produced a copy of a letter from Mr. SMEATON to the Earl of KINNOUL, dated the 8th instant, and also two letters from Mr. SMEATON addressed to the clerk, dated the 6th and 10th instant, all of which were read.

Mr. Gwin gave in to the meeting his report, of which the tenor follows:

The REPORT of John Gwin, in answer to orders by him received, and appointed to his inspection and consideration at a meeting of the commissioners for building a bridge over the river Tay. February 27, 1766.

1st. UPON founding with what instruments was practicable to get down to prove the stratum of matter in fundry places across the river Tay, from North Inch to the opposite shore in James Bisser's garden, as well as the state of the river and metals would permit, find the stratum of matter in the different soundings are as follow: that on founding and boring in fundry places both above and below JAMES BISSET'S garden, to the extent of about 150 feet in length up and down stream, found a rock close in shore upon an average lying upon 2 feet 9 inches below the top furface of the gravel, and extending itself from the shore, towards North Inch, as near as I could judge, about 300 feet, before I could exactly say I thought it left, and continued to be very level, not varying one foot in depth in the above length. This top crust, or supposed stratum of rock or hard cemented gravel, consists equally alike in all different places of trial by boring, and appears to be a shaly hard consistence for about 8 inches thick; but upon further speculation, to prove its confistency of metal, found that we could force a sharp-pointed iron bar down 6 feet deep (in some parts 8 feet deep) into the said stratum of shaly matter, always observing the bar went moderately easy after it got through the upper crust beforementioned, and did not begin to fasten till at about 8 feet or 9 feet in general, and then it came to a matter much more firm and solid. From this place, which is not quite the half over to the North Inch, the stratum grows somewhat softer after we got down 7 feet from the top surface, which seems to run, on a medium, nearly on a level, it being a stratum of sound firm gravel, and then, for about 2 feet 9 inches, it appears to be a fandy gravel, (by what our rods brought up) and under that, at about  $10\frac{1}{2}$  feet from the top surface, on an average, we come to a firm sound gravel, as before.

Upon boring on the shore in James Bisset's garden, in two places, at the distance of 30 seet from the water's side, find the stratum of matter to be from the top surface to 6 seet deep a blue corn mold earth, and from that down  $5\frac{1}{2}$  seet a quite shear sand intermixed with a little gravel, which both together makes 11 seet 6 inches, at which depth we came at the rock, which lies nearly level, and rising in its bed but very little up the hill. On the North Inch side on land we bored, we find corn mold earth to the depth of 5 seet from the surface, and from that to the depth of 3 seet a sharp shear sand, then came to a loose gravel for about 2 seet, after which it continues looseish to about the depth of 8 seet, at which depth it appears to be a quite solid gravel, and is all the particular

particular situations of the stratum of matter consisting in the bed of the river, across from shore to shore, at the abovementioned place, to the best of my opinion.

2d. Upon sounding the aforesaid river from the town-house to the opposite shore called bridge end, find the metals in the bed of the river as follows. Having drove a sharp pointed iron bar in sundry places up and down stream for near 120 feet in length, but could find no place to get the bar down from the upper surface about 4 feet before it met with some of the ruins of the old bridge, which lay spread up and down in that channel for about 60 yards facing the high street, and extending about 80 or 100 feet breadthways across the river; after which, on sounding from thence to about 80 feet of the opposite shore in sundry different places, sound the stratum of matter so soft, as to admit a bar being forced easily down into it 12, 14, and 16 feet, and even at that depth no solid matter appeared. The soil, from what I can judge, is a sandy clay, at about 6 or 7 feet from the top surface, which is all the particular description of the strata of matter in the above situation, to the best of my opinion.

3d. Regarding which of the two before-mentioned places is properest to erect the bridge, my opinion is, that the suitablest place for the bridge to be built near the town of Pertb, is from the North Inch to the opposite shore, in JAMES BISSET's garden, (for reason 1st.) The river is more extensive in breadth than in any other place adjacent to the town. (2dly.) In extreme floods the water having liberty to extend itself to a great surface, and by the intended situation of the bridge being at a proper distance from the mill lead, consequently will give room and scope for a great quantity of water to issue in there on the down-stream side of the bridge, which will cause a lethe of water to constantly be recoiling back to the bridge, and meet the currency, and thereby ease in a great measure the pressure and weight on the bridge. (3dly.) Its situation in this place is much more desirable, as it is across a ford, which by the best accounts I can learn has not been known to shift these many years. (And lastly.) It has been remarked, that during the late storms, wherein the Tay has discharged great quantities of ice, which has floated up and down with the tide, it was not known that scarcely any ice went up above the faid ford, but has been known to gorge up the river in different places to abnost incredible height below the said ford, particularly at or nearly opposite the town-house, which would be a very great obstruction to the water-way in a flood time, provided the bridge was pitched upon to be built across this part of the river; besides, another reason in my opinion against this situation not being suitable is, that the river is more contracted from shore to shore, it being but 567 feet across from the town-house wharf to TROMAS TYFF's house, besides its bounds are shorter than that, as much as it is across from the wharf side to his house, which is 34 feet, which reduces the water-

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way so much less; and (3dly,) on continuing the proper length of the bridge, find that according to plan the bridge foot will terminate above 50 feet above Waller Gate Street. which will render the low rooms of the dwellings contiguous thereto invalid, by the bridge being so high above them on both sides, supposing all other circumstances agreed with its situation.

4th. Regarding the part of the river in which the first pier should be fixed, am of opinion, that one of the center arch piers will be as difficult as any, for reason, if we are to go down to that lower bed or stratum of hard gravel, it will be a difficult matter to drain it, for the getting out the excavation and foundation laying, or the third pier nearest the bridge end shore, it being the deepest water there.

5th. Regarding the quantity and quality of fundry materials in timber necessary for the erection of one pier, in making a coffer-dam and pumps and engines, and all other materials, &c. fuch as tackles and shear-poles for the masonry, and hand and wheel barrows for the excavation, and likewise, in case the pier should be ordered by Mr. SMEATON to be piled in the foundation, the stuff wanted will be as followeth: for the coffer-dam and other uses 2274 cube seet of oak and elm, and 150 cube seet of Riga timber, about 200 superficial feet of ash plank for barrows, about 15 Assar baulks, 20 feet long, for stages, and tackle poles, &c. about 30 Dantzick 3 and 4 inch planks, 20 feet long, for stages and runs for the barrows in the excavation, likewise about 30 inch and half Dantzick planks for engines, and pumps, &c. about 14 or 16 feet long; and lastly, if it comes to be a timber foundation, (not that I pretend to know in what manner Mr. SMEATON will pitch on it to be done,) but only in case it should so happen that he thinks it necessary; in such a case, I have made a rough calculation what stuff we should have in readiness against such thought as may to him seem best, which appears it cannot be less than 1000 cube feet of oak and elm, though I think it would be full enough, only it would be proper to have some to turn our hands on.

Regarding what number of my workmen I think necessary to bring with me from England, I intend to bring two men and my apprentice. As to terms, Gentlemen, as they will be employed in your fervice about five months, or nearly fo, and then have to go home back again, I think I cannot engage them otherwise than at 14s. per week each man, and the apprentice to be 7 s. with their time and moderate expences on the road going and coming paid them.

7th. Regarding the quantity of other workmen necessary in my branch for carrying on the pier, to be assisting with my men, I think four carpenters and ten labourers will be sufficient for the expediting the work; but the latter will not be wanted till we begin to take off the water.

With the bleffing of God, if I continue in good health, I propose to be at Perth in fix weeks time, from the fetting off on my journey to my coming again, provided all materials, or part to begin, be got to proper place to work, upon notice, which I presume will be sent; and I think, if agreeable to you, Gentlemen, that Mr. SANDE-MAN's saw-mill will be the properest place to work up the materials, as the stuff may be sawed by the mill and worked up there, and then sent down to the work by water as wanted, and not be liable to be any of it lost by floods.

JOHN GWIN. Signed,

Which report being read, the Commissioners direct Mr. Gwin that he will immediately, upon his return to England, communicate the faid report to Mr. SMEATON, and desire Mr. SMEATON to ascertain the materials which he shall think most proper and necessary for the timber work that is to be prepared for erecting the experimental pier; and that he would, as soon as possible, transmit to Mr. PATRICK MILLER an account of the materials so ascertained by him.

The Commissioners approve of Mr. Gwin's terms upon which he proposes to bring down from England the two workmen and his apprentice.

The Commissioners recommend it to Mr. Gwin to regulate his return so that the necessary preparations may be ready at the time it will suit Mr. Smeaton's convenience to be here; and they direct their clerk to deliver to Mr. Gwin a copy of their minutes in so far as relates to his report.

Extracted from the records of the said Commissioners by me

PAT. MILLER, Clerk.

DESCRIPTION and METHOD of fixing the foundation of the second pier of Perth Bridge, according to the plan.

# Method of fixing the coffer-dam.

THE gravel turning out harder than was expected in the last pier, and it taking up. much time in driving the piles of the coffer-dam down to their proper depth, and allo finding them very difficult to draw, and much shattered when drawn, I propose for this pier that as many additional piles be procured as will fet the whole at the distance of 9 feet from sheeting of the base of the pier, and to drive them no farther than to fix them firm in the ground, which if that happens at 2 feet will be sufficient. The dam being then compleated to its proper height, in order to guard against filteration of the water under the bottom of the piles, I propose to throw in all round on the outside a quantity of gravel and corn mold earth mixed together, so as to lay rather sloping against the piles, and extending about 6 seer all round: the gravel being mixed with the earth, will not only augment its quantity, but prevent its being carried away by the stream, the use of the earth being to choak up the chinks and pores of the gravel upon the bed of the river. I apprehend about a cube yard of compound matter, to a yard running, thrown in, will be fufficient, observing to begin the work at the salient angle up stream, and proceeding gradually downwards on both fides, clofing at the salient angle down stream.

# Method of making the excavation.

The pumps being fixed, and the water pumped out, begin the excavation no larger than the base of the pier, and having got down a space in the middle to its proper depth, increase it in width and length till the area is clear for driving the piles upon which the foundation frame is intended to rest, and no more, leaving the matter on the outside of that area to form its own slope toward the coffer-dam, so that the rest of the area will be lest solid, to support the sheeting of the dam; and if any part seems seeble, or likely to give way, let it be strengthened by driving piles for supporting slate on edge, as the nature of the ground and circumstances shall shew to be necessary, observing, in beginning the excavation, that the matter be thrown out all round, so as to secure and strengthen the matter first thrown on the outside of the dam.

The depth of the excavation will be found by the following rule. It must at least be excavated 3 feet at a medium below the natural surface of the gravel where the pier stands;

stands; but if this closs not carry down the base of this pier within 2 feet of the level, at which the base of the sirst pier was fixed, let the depth of the excavation be increased till it is within 2 feet of the former depth.

Method of fixing the foundation, according to the plan.

The excavation being made, as far as is above directed, let the 21 piles, upon which the frame refls, be driven into their proper places: these piles are to be to inches heads, and of 6 feet long, supposing the gravel of equal strength with the last, but if there is any reason to suppose it stronger or weaker, the length above mentioned should be increased or diminished. This being done, and the pile heads reduced to a level, lay down the frame thereupon, which I suppose to be ready prepared in the yard, with the tye beams ready fitted with dovetails thereto, and being trenailed down upon the respective pile heads, proceed to drive the sheeting piles, which may be of oak, elm, beech, or fir, as can best be got. I suppose them to be of 6 feet long; they may be driven plain, as shewn on one side, as was done at Coldstream Bridge, but would be preferable if rebated, as shewn on the other half. The choice of the method depends on circumstances; if, from experience of the other pier, they are like to drive regular, without tearing of the rebates, by meeting with great stones, &c. then they will both drive more regular, and hold firmest by being rebated, but if they are apt to split, then it will be as well to fave that time and labour, by making them plain, and more especially so if the disference of expence in workmanship, or hindrance of time in doing it, is likely to be a. material object, in that case the rebating may be omitted.

N. B. If driven plain, the breadths of the piles are not material; but if rebated, narrow piles will enhance the workmanship in preparing. In order to save timber (and row piles will enhance the workmanship in preparing. I propose to groove the especially if fir piles are made use of, it will be much stronger) I propose to groove the piles on both sides, and to nail in the tongue, which, if fir piles, may be of harder piles on both sides, and to nail in the tongue, which, if fir piles, may be of harder piles on both sides, and to nail in the tongue, which, if sir piles, may be of harder piles on both sides, and to nail in the tongue state tongue state the tongue state the tongue state to make the tongue state the tongue state to make the tongue state the tongue state the tongue state to make the tongue state the tongue state to make the tongue state the tongue state the tongue state the tongue state to make the tongue state the

The tops of the sheeting piles being reduced to a level with the string pieces (and spiked thereto as they are driven) the outside must be reduced to a regular breadth, so as to take the notched stones in a line. This being done, the rest of the bearing piles as to take the notched stones in a line. This being done, the rest of the bearing piles as to take the notched stones in a line. This being done, the rest of the bearing piles are to take the notched stones in a line. This being done, the rest of the the top of the must be driven, beginning with the outside rows, and cut to a level with the top of the string.

string pieces; these piles may be of 6 feet, more or less, according as the others are found to go.

The fetting must be compleated by first underpinning the string pieces and tye beams, as firmly and equally as they can, by moderately driving stones under them; and lastly, the other spaces to be set, and well drove down as before; but before they are rammed down, the joints of the setting should be filled by sweeping in dry lime mixed with sand and small gravel, that when drove down the whole may be compact together.

When the pier is got above low water, I would have the matter taken out for 4 feet wide round the pier, down to the level of the top of the notch course, and filled with good lagging as before, standing somewhat higher than the natural bed of the river, and the rest of the space covered with rubble to the sides of the dam.

N. B. I suppose the bearing piles to be sufficiently drove, when it takes 20 blows of a sufficient ram to drive an inch, and the sheeting piling to be so when it takes 40 blows to drive the same quantity; but the sheeting piles should be drove as near to a regular depth as possible.

J. SMEATON.

Austhorpe, April 23, 1767.

P. S. I don't mean to set aside the use of such materials as were prepared according to the plan of last year, unless utterly inconsistent with the present.

# PERTH BRIDGE.

Perth, October 5, 1787.

HAVING this day viewed the bridge of Perth, I have the satisfaction to observe every thing relative to it in perfect good condition, the walking path over it excepted; which, from the want of hardness in the stone wherewith it has been laid, is not only much worn, but from the hard pebbles imbodied in the stone itself is become very rough and uneven. For the effectual restoration of this part, nothing would be so compleatly durable as to remove the present stone-work, and relay the same with Aberdeen granite of the same depth as the present. But as the present stone-work of the walking path appears

to me to lay compleatly firm and folid, and being shewn a sample of the Kingudie slat paving, which I understand can be procured of any thickness, with parallel surfaces, and also appearing to me to be of a nature sufficiently durable, I apprehend the work may be executed in a substantial manner, as follows:

The stone from Kingudie being procured of 4, 5, or 6 inches thickness, as can be most conveniently had, and of such lengths as to make good the whole breadth of the walking path without a joint, but of promiscuous breadths in the direction of the bridge, I would advise to chissel or broach off the upper surface of the present walking path till it comes to a regular height, and then with good mortar to lay down the Kingudie slooring, close jointed, upon it, making the joints of the flooring with the best Pozzelana mortar; and in case there is Pozzelana remaining in plenty, it would be well to give the mortar wherewith the flooring is bedded an allowance of Pozzelana, as suppose, half the quantity; observing to level the surface of the present mass of stone in such manner as to allow a drip or declivity from the parapet towards the carriage way of about  $\frac{3}{4}$  of an inch; and also to make the breadth of the new flooring about  $\frac{3}{4}$  of an inch short of the present breadth, so that the tread of the carriages being taken off from rubbing against the Kingudie flooring, it may remain undisturbed being defended by the solid of the present; and in the same way the walking path may be set with Aberdeen granite, provided it is worked to a parallel thickness.

With respect to the paving of the bridge, there is no objection to it as to the structure, this being merely a matter of convenience, of which those who from their local situations observe and use it can be the best judges. I have only to observe, that the Aberdeen granite paving is not only the most durable of any that I am acquainted with; but, from granite paving is not only the most durable of any that I am acquainted with; but, from its roughness, the horses seet are the most steady, and hold the sirmest in drawing upon it. The blue whin is the next in degree; so that where the blue whin is procured upon the place, I cannot think it necessary to send for the Aberdeen granite from a distance.

Having viewed the bulwarks that have been erected opposite the Inch upon the northeast side of the river, I am of opinion that all such works as cross and intersect the stream of the river, or interrupt the water from gliding freely away, are the means of increasing the stress upon other parts, and therefore, as affecting other properties, should be avoided, the stress upon other parts, and therefore, as affecting other properties, it should be by When properties want a defence against the incroachments of the waters, it should be by disposing those defences at the foot of the banks, in a direction parallel to the stream, and without interrupting its free course.

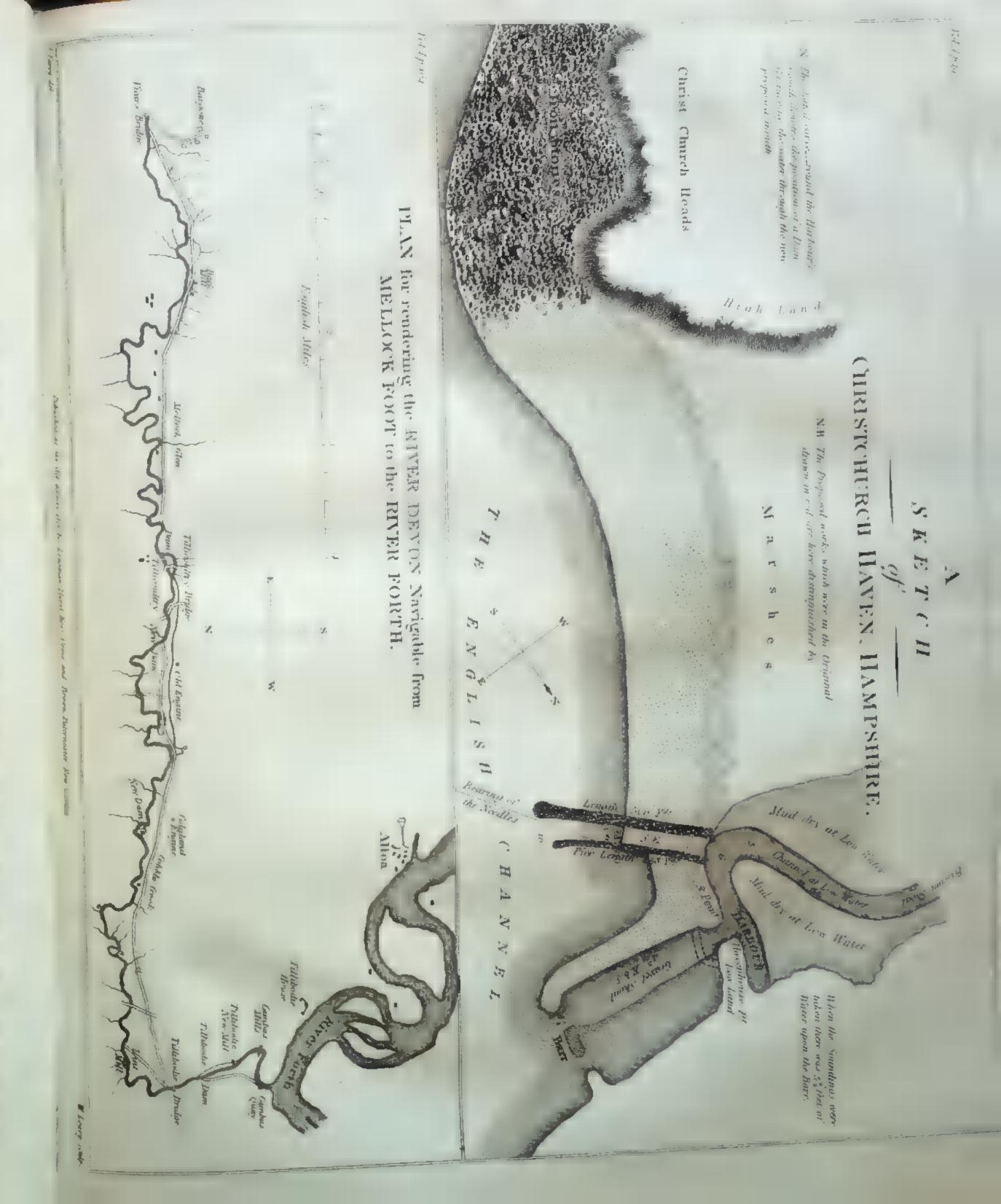
J. SMEATON.

#### CHRISTCHURCH HARBOUR.

The REPORT of John Smeaton, Engineer, upon the harbour of Christeburch in Hampshire, from a view thereof taken the 20th and 21st of May, 1762.

THE harbour of Christehurch is situated in the bottom of a deep bay, sormed between the isles of Wight and Purbeck, and at the mouth of the two large united rivers Avon and Stour; the passage of which to sea is between two natural points of land not much above 50 yards assumer at low water, within which points the river forms a large inland bay or bason, which is properly the harbour or haven of Christehurch, and is defended from all winds: with those outlines one would be naturally led to expect a good harbour, capable of receiving a number of large ships; yet, notwithstanding these great advantages, nature has ordered it otherwise.

About a mile or better to the S. W. of the harbour's mouth begins an high point of land, called Christeburch Head or Heads, for the coast, in running further to the S. W. forms another, which makes a double head, with a small recess or bay between; these heads, as well as a considerable part of the coast extending westward therefrom, stand bold upon the sea, the foot thereof being washed by its waves at high water. Those heads have formerly extended much further into the fea than at prefent; but being composed of a loose sand, intermixed with some quantity of loose iron stones, the action of the sea upon the foot of these cliffs in time of storms brings it down in great quantities, and is driven by the violence of the seas with wind from S. to S. W. into the bottom of the bay, and there being subject to no counteraction by the opposite winds, it has not only greatly obstructed the bottom of the bay with fand, but has spread itself to a confiderable distance from the shore. It further seems to me that the harbour's mouth has formerly been much more extensive than at present, having reached even to the heads; but the sand gradually coming down from the cliss, and being driven into the haven by the S. W. and S. E. winds, has gradually formed marshes to the N. E. of the high lands, and thereby drove the mouth or channel of the river gradually to the N. E. and again, by the blowing of the fand, left dry at low water, by the S. F. wind, it has formed a range of hommocks or fand-hills, extending from the heads north-eastward to the fouth point that now forms the harbour's mouth, and has thereby formed a natural bank, part of which separates the bason, now composing the harbour of Christchurch, from the sea. The sands thus moving seem to have forced the mouth of the river as much to the N.E.



N. E. as they well can be; and undoubtedly the whole had been long ago shut up, had it not been for the powerful re-action of the fresh waters continually pressing toward the sea from the two rivers aforesaid, which, in wet seasons, as they drain a vast track of country, must be very considerable; and indeed, by the power of such a collection of fresh waters, great things might be done, did not nature throw out another rub in the way, and that is the small slow of the tides at this place.

The great depth of this bay from the main channel tide, the moalness of the waters occasioned by the sands beforementioned, and the distraction of the current in going different ways round the Isle of Wight, I look upon to be the most probable cause of the smallness and irregularity of the tides here. It is not reckoned that the spring tides rise more than from 5 to 7 feet, and the neap tides from 4 to 6; so that it sometimes happens that the neap tides are higher than the springs, depending much upon the course of the winds; the tides are said to be highest with a S. E. wind, and least with wind at N.

I am also informed, that three hours after the regular time of high water, when the main tide in the channel begins to set towards the west, a second tide is formed in this bay, which is generally highest at neap tides, and that the ebb between the two tides is from 8 or 9 inches to 18; which second tide, proving a check of the reslowing power of the land waters, tends to weaken their force in getting to sea.

From the circumstances before described, viz. the statues of the bottom, the constant motion and increase of the sands, and smallness of the tides, I cannot statter the inhabitants ever to expect an harbour at Christehurch of any great depth or capacity; yet, at the same time, it seems to me capable of great improvement, as will appear from a further description.

Between the points I found a considerable depth of water, but as the width of the channel greatly enlarges without the points, the depth diminishes, and at the distance of about 200 yards an hard gravel shoal is formed, and still surther out the bar. From the points to the bar the channel lays E. by S. and from the S. point there runs out a sand, which is dry at low water, and extends from the said point on the S. side of the standard of the channel, and in a parallel direction thereto, as far as the bar. This view was taken on the second and third days before the change of the moon, so that the spring tides were scarcely set in.

At this time I found 16 feet water between the points, 4 feet 9 inches upon the gravel shoal, and  $5\frac{1}{2}$  water upon the bar, and in the road, which lays about half a mile further out Vol. I.

out in the same direction, 16 seet water; the bottom is said to be a strong blue class. the Needles bearing S. E. by S. and Christeburch Heads S. W. and just open one with the other. Within the points the channel turns S. W. by the fide of the hommacks before. mentioned, and from 16 feet, as it is between the points, comes to 7, 6, and 5 feet.

Christehureb Quay lies about two miles up the river from the harbour's mouth, between which there are the following shoals, beginning at the harbour, viz.

Friscum Shoal, water thereon 4 feet 9 inches, (when  $5\frac{1}{2}$  at the bar as above) a loose gravel or shingle 2 feet deep, then turns harder. Ganbury Shoal, 5 feet water, bottom foft mud and fand. Saltmard Corner, 5 1 water, bottom loofe gravel or shingle. The Pick had 6 seet 3 inches water, and a loose gravel or shingle bottom. There was no other place in the river but what sounded 6 sees or upwards at the said tide.

About t furlong from the S. point of the harbour's mouth, towards the S. W. is run out a kind of jetty or pier in a straight line, composed of round lumps of iron stone, which have been brought from the Heads; its direction is S. E. and extends from high water mark 256 yards; the Needles bear from thence S. E. by S. so that it is land-locked thereby a point of the compass; its top gradually declines from the shore towards the fea, the whole being uncovered at low water, but all or the greatest part covered at high water. Round the end of this pier I found about  $7\frac{1}{2}$  feet water, and at about double this distance from the shore about 10 seet, (when  $5\frac{1}{2}$  upon the bar) the water being rather better to the N. E. than to the S. W. of this line, the whole bottom being fand, and almost regularly inclining from the shore in the proportion abovementioned.

From information I learn, that the aforesaid pier or jetty was erected in the reign of King CHARLES the Second, and intended for securing a better passage into the harbour, and that for this purpose a cut was made through the hommacks, so as to let the water through the same out of the harbour, and so as to direct its course to the S. W. side of the pier.

This pier, it seems, was intended for the N. E. pier; another pier being designed on the S. W. side of the channel; the other passage in or near the present place was then stopped up with piles, &c. at a considerable expence: this course was maintained for some time, and a deep channel was made by the back waters alongside the pier of 15 or 16 feet deep; but then the matter being deposited, and the force of the land water being spent as soon as it quitted the end of the pier, there still must remain there 2 bar of the same height as the present bottom; however, as that bottom is at least 2 feet lower than the present bar, it would make at least 2 seet more water into the harbour, which must, of course, prove a very great improvement so long as it lasted. But before a long time had passed it happened that the back waters, not finding a passage to fea fufficiently ready through this new channel, broke over, and forced themselves a fresh passage at the present place, which has ever since continued, and the artificial one was presently shut up by the sea.

From a due confideration of the facts and circumstances above recited, it appears to me as follows.

1st. That from the tendency of the land waters to open and preserve themselves a passage to sea at or near their present place, and from the tendency of the sea to shut up any passage made to the S. W. that the present course is best adapted by nature to be maintained: this is further confirmed by the bottom of the road, which laying further out in the same direction, is clear of sand; but as the distances from the points to the bar, and from thence to a sufficient depth of water for an entry to a tolerable harbour, to which place two piers ought to be carried out to confine the land waters, and protect the channel from the driving in of the fand, in order to render the same effectual; I fay, the great length required for such piers appears to me likely to be attended with too great an expence, added to the great trouble and difficulty in moving the gravel shoal before mentioned, otherwise, in my opinion, this construction would be the least exceptionable.

2d. It appears to me that the grand mistake in the former attempt consisted in constructing the wrong pier first; or in other words in making the channel on the wrong side of it: otherwise, for ought that to me appears, it might have maintained itself an open passage to this day; for had the S. W. pier been built first, or what amounts to the same thing, had this been made the S. W. pier, by making the passage on the N. E. side of it, then it would not have only defended the passage from the sands brought down from the S. W. by the action of the winds and storms from that quarter, but the sea, by breaking over the top of it, would have tended to have deepened the channel on the leeward fide; whereas by making the channel on the windward fide, it would tend to intercept the sands, and thereby immediately to fill up the channel, had not the superior force of the back water carried it out as fast as brought in; so that I rather marvel a passage was ever this way obtained, than that it should be filled up in the way it was managed.

That this must be the case in some measure, appears from the manner in which the fand now lays contiguous to the pier; for notwithstanding it is within 2 or 3 feet of the

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top, yet it lays on the S. W. fide at least a foot higher than on the N. E. Indeed I cannot account for a conduct so absurd, otherwise than by supposing the projector imagined the sands to be immoveable, with respect to the winds and seas, and not in a travelling state; and observing the strong tendency of the channel to travel to the N. castward, proposed to stop it by interposing the pier. From this attempt however, though unsuccessful, we may learn how strongly the land waters acted, and what may be done by better management in the same situation.

The direction of the pier S. E. is very good, for vessels may sail in or out with a S. W. wind; it could not be pointed more southerly, so as to give advantage to vessels going in with wind nearer west, than they can now do, without giving advantage to the seas from S. S. E. to roll more directly in, as it would then not land-lock with the needles, but point to the open sea; its situation is also very good, as it stands almost direct in a right line with a reach of the river, and if a vessel should not make the entrance of the barbour, they will have the road to the leeward.

I would therefore advise to construct another pier parallel to the present one, but on the S. W. side thereof, and at the distance of about 240 feet from middle to middle; and when this is carried out from 50 to 100 feet further than the present pier, then to attempt to open a passage through the hommacks, so as to turn the water between them, and at the same time to divert the water from its present course at low water by a catch-dam of rough stones, or by a composition of piles, sascines, stones, &c. by these means a sufficient channel being procured between the two piers at low water, that channel will gradually deepen, and the present channel being deprived of the greatest part of the reslowing power, the sands that are now kept out by the same will begin to close in, and in time will form hommacks so as make an entire stop at high water, and the progress thereof, as occasion may shew necessary, may be helped by art.

By these means the earliest advantage may be taken of the undertaking, and vessels drawing 8 feet water may be brought in at a midling spring tide; and as I would advise the whole to be performed by throwing in of stones upon the same principles as the prefent pier has been built, the piers may be gradually lengthened, constantly advancing the S. W. pier before the N. E. and it appears, that by extending the piers to double the length of the present, that is, to the length of about 500 seet, there will be  $2\frac{1}{2}$  seet more water, that is, there will then at mean spring tide be  $10\frac{1}{2}$  feet water, and at neap tides  $9\frac{1}{2}$  feet, which will make a very good harbour for small merchant ships, coasting vessels, armed cutters, &c. And as it appears that an extension of about 250 feet pro-

cures  $2\frac{1}{2}$  feet water, it follows that every too feet extent of the piers will procure an additional foot of water, so that the improvement of this harbour may be carried on to any extent, by gradually lengthening its piers, as time, circumstances, the utility of the harbour, and ability to execute, shall suggest.

I do not think it necessary to do any thing to the present pier, till the west pier is carried out as directed, and the water let in between them; but I would advise the west pier never to be lest till it has got above high-water. It must at first be made considerably higher than high water, for as I would not advise attempting to dig away the sand for a foundation, whenever the current is turned against it, it will settle very considerably, and unless good body of stone is originally laid, may settle so much as to make it dissicult to add to the mass at top. It is for this reason I would not advise to make the present pier the west pier, for having had a deep channel on the west side of it, the matter thereof on that side had got sufficiently compacted to a due depth; but was the channel made on the east side, the foundation being there shallow, would be undermined, and occasion it to settle asresh, and require a large addition of materials to make it up to the same height.

As the tides are faid to rife from 4 to 7 feet upon the bar,  $5\frac{1}{2}$  will be the mean, which was what I observed; and as I found no part of the river between the harbour and the town of Christoherob, but what, at that time, founded 6 feet and upwards, except the shoals before specified, all which are composed of soft and loose matter, and of no great extent, I look upon it as very practicable, by dredging, to make good a 6 feet channel from the harbour to the town quay, at a mean tide, which will be very sufficient for all kinds of lighters and small crast. This may possibly be done by the river itself, whenever it gets a more sufficient outlet to sea; and much more cannot be expected, without a very considerable expence.

The iron stones now laying upon the sands under Christeburch Heads, are a very proper material for the construction of the works abovementioned; but I sear they will not be found in sufficient quantities, if not, rough unformed stones may be brought from Peveral Point, or Portland, the cap of which is resuse, and will answer as well as sincest stone.

I have added a sketch of the harbour, as it appeared to me on view, and the meafures above specified, wherein what is done in red is the proposed works.

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As this is a work that depends much upon circumstances, it is not easy to make a tolerable estimate; yet, to give all the satisfaction in my power, the best I can judge of it is as follows.

ESTIMATE for the works proposed to be constructed at the harbour's mouth, according to the preceding scheme.

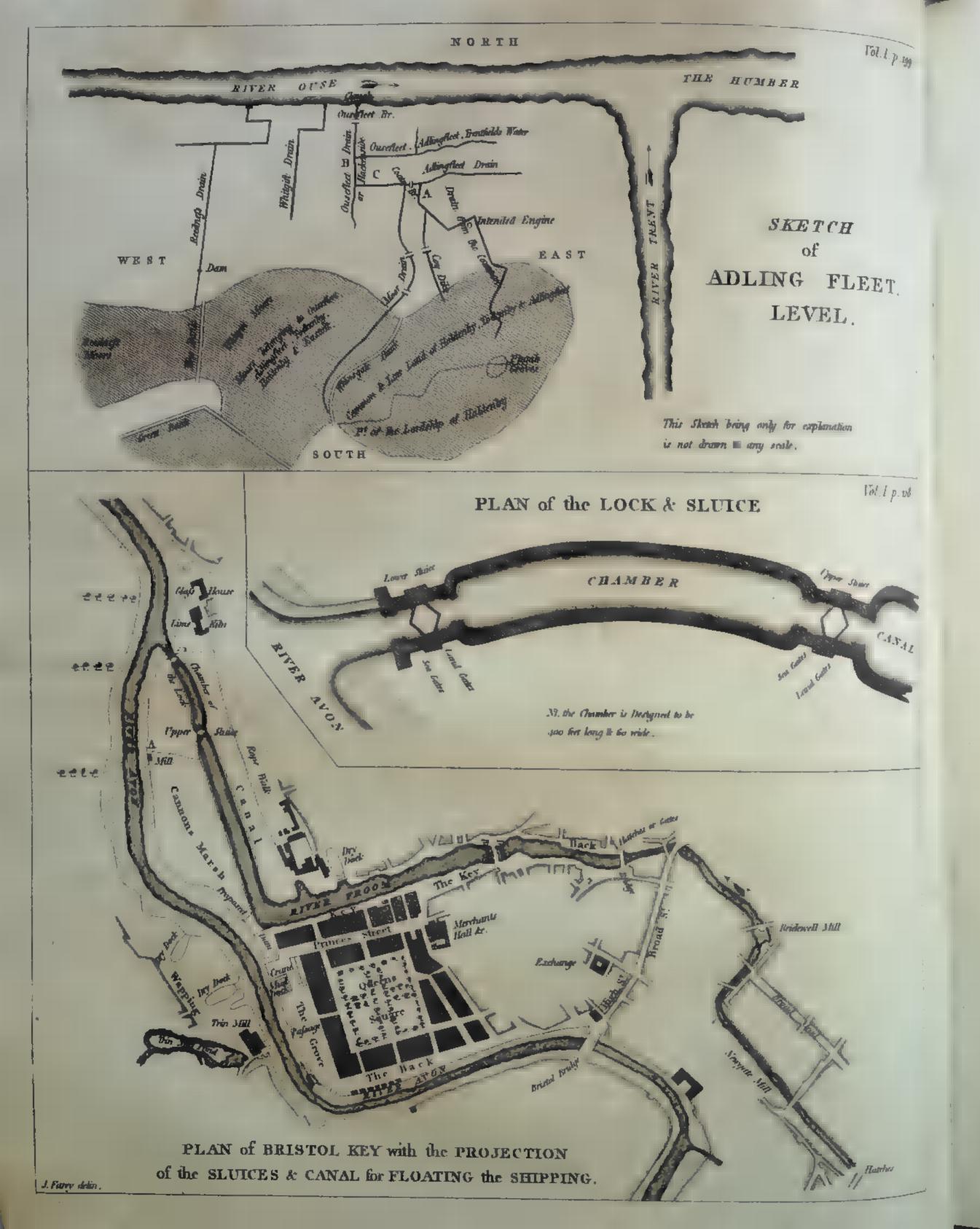
	L.	£.	đ.
I suppose the great S. W. pier will, at a medium, take 224 cube feet of matter in each foot			
running, and for 1500 feet 330,000 feet; this, allowing 12 feet of iron stone to the ton,			
will produce 28,000 tons; and supposing this to be brought from the heads, and laid in	2800	0	13
place at 2s, per ton, will come to		V	
For the prolongation of the north-eastern pier 210 yards, I suppose 168 cube feet per foot			
running may be sufficient, and this for 630 feet is 105,840 cube feet, which will make	832	Ó	0
8820 tons, at 21.		~	~
For making a cut through the hommocks, at a medium, 66 yards long, 66 yards wide, and			
3 yards deep, will contain 13,068 cube yards, which at 4d. comes to 217 l. 16s. but as			
fome work will be required in clearing away fome of the fand between the piers, till a	300	0	0
passage can be procured, if for this service we reckon 821. 4s. the whole will be			
For covering the border of the new cut with Hones, so as to prevent its washing, and there-			
by to prevent the water from getting part behind the piers; this, at a medium, being faced	150	0	0
up half a yard thick, will take about 1500 tons, at 25.			
For making a catch-dam to force the water of the haven through the new cut and between the piers, at low water; this, if constructed wholly with rubble, and being supposed, at a			
the piers, at low water; this, if cointracted whonly with factor, and bong improved will re-			
medium, to contain 70 feet cube per foot running, this, for 720 feet in length, will re-	420	0	0
quire 4200 tons, at 25.	455	0	0
To incidental expences, at 10 per cent.			
	5007	0	0

N. B. As the quantities are given, if the iron stone can be moved cheaper than above set down, the saving will be in proportion; but if the quantity above specified cannot be got from the heads, what will be necessary to be brought from *Purbeck* or *Portland* will be at an advanced price, and will at least, I suppose, come to 5 h per ton; but it is to be noted, that one ton of this stone makes 16 feet.

Auftborpe, August 13th, 1764.

J. SMEATON.

ADLING



# ADLING FLEET LEVEL.

The REPORT of John Smeaton, Engineer, upon a view and observation taken of the level of Adling Fleet, &c. from a plan of the said level, taken by Mr. Charles Tate, Surveyor, in the year 1764.

IN the year 1755 I was employed by the owners of the manor of Haldenby to take a general view of this level, in order to form a scheme for the drainage thereof; and finding that the great desect laid in the drains and out-sall clough, I made a report, showing how these desects were to be remedied, to the general advantage of the whole, as well as Haldenby in particular, as will more fully appear by reference to the said report, not supposing at that time that the proprietors would be willing to be at the charge of getting an act of Parliament, in order to enable them to make new drains in any more proper direction.

The prefent view and report being made at the general request of the principal proprietors of the said level, who not scrupling the expence of an act of Parliament, in case it should be requisite, I have taken a further and more minute, as well as unconfined, view of the whole; and though from hence it appears that a more eligible course of drainage offers itself than the old one formerly proposed, yet it also appears, that had my former directions been put in effectual execution, the proprietors would have found no occasion for a second application, and would have reaped the benefit of the improvements during the intermediate time.—I also find the coincidence of the levels taken then, and now, surprisingly great, considering the badness of the season then, and that the greatest part of the low grounds were then under water, there being but a inches difference between the sall from the low part of Haldenby Common (which is the lowest land) and the shoor of our fleet clough, as taken then and now, as will appear by comparison of the former observations with the present; but as the latter observations were made under more savourable circumstances, and with more accurate instruments, I shall chiefly rely upon my last observations, which are as follow.

about of Hackenisks of Org	esteet	r.t.	A151
Rife from law-water mark at the Oufe, September 1764, to the floor of Hackenfishe or Ong	-	3	OI
Clough in the design at Coat's Bridge,	-	4	9
Clough,  Rife from the floor of the Clough to the furface of the water in the drain at Coat's Bridge,		7	91
Diffe of water from low-water mark at the Ouje to Coat's Bridge,			

Many parts of the bottom of Hackensyke Drain are not more than 14 inches below the level of the surface of the water at Coat's Bridge.

Rise

Rise from low water at Trent Fall to the surface of the water in the drain at Coar's Bridge,				
Fall of the Ouse from Hackensyk: Clough to Trent Fall,	1	7±		
N. B. The rife of the different points of the land above the water at Coat's Bridge, is inserted in circles upon the map.  From Coat's Bridge, for the run of the water through the drains, I allow to the stagnant water on				
N. B. The depth of this stagnant water was in general about 9 inches; from this stagnant water to Green Bank, the water along Enftoft Drain was in general stagnant; but the sum of the rise		2		
Rise from thence to the mean surface of the land near the head of the division drain, between	0	3		
Enflost and Whitgift, on the north side of Green Bank,	0	7		
Rise from Coat's Bridge water to the general surface of the land on the north side of Green Bank, Rise from the general surface of the lands on the north to the surface of the water in East of the		0		
Drain, south of Green Bank, which were upon a level with the lowest lands there,	1	21		
Rife from Coat's Bridge to the furface of the lowest lands in Eastost, south of Green Bank,	2	2 3		
Confequently,				
Ou/e at	Trent	Fall.		
Hackenjyke Clough.	Ft.	In.		
The lowest lands in Haldenby above low-water mark at - 7 2½  The lowest lands in Eastest and Whitgist Moors, north of and contiguous	8	10		
to Green Bank, 8 9½	10	5		
The lowest lands in Eastest, south of Green Bank, 10 0	11	$7\frac{1}{2}$		

As I found no considerable quantity of water remaining upon the tract of country under consideration, except upon Haldenby Common and adjacent places, it follows from hence that, agreeable to my former observations, Haldenby Common is the lowest part thereof, and consequently what will drain this part, will, of course, drain all the rest; and fince this part lays 4 feet 2 inches above the floor of Hackensyke Clough, it may be wondered why 9 inches water should remain thereon in a dry season; but as it also appears, that many parts of the bottom of Hackensyke Drain lay but 14 inches below the water of Coat's Bridge, it will of consequence be not more than 7 inches below the land furface of Haldenby Common; from which if we take 3 inches for the declivity of the water, to produce a sensible run to the place of obstruction, there will remain only 4 inches for the depth of water upon the bottom of the drain, which is so small a body that the water cannot be run off in the course of the summer, if it should prove showery; nor otherwise, till it is evaporated by the sun and winds, which are the only means by which this piece of ground can be drained, as things are now constituted.

I thought

I thought proper more particularly to remark this fact, because it at once points out the cause and cure of the evils that attend the whole level.

That Haldenby Common admits of drainage by Hackenble Clerch, even as it now stands, appears hence.

	Pt.	In.	Pt.	In.
The whole full from the furface thereof to the Charles door being		-	4	2
Suppose 6 inches thickness of water to go over the first loor	5	-6		
The farface of the water being reduced a feet within foil, mak, a complete drainage,	ž.			
		fl		6

Remains the declivity of the water's furface in the drains between Hallen's Common and the Glong's

The distance by the course of the drains, straightened according to A B G H I e f. will be 3 miles 2 1 furlongs nearly, which is full 6 inches per mile, which is with a the limits of a good drainage.

Hence it appears, beyond a doubt, that the whole level may be drained by Thick of he Clough, as it now stands, provided drains of proper depth and capacity were made correspondent thereto; but as that Clough lays full 3 feet higher than low-water mark, it is capable of being laid fo much lower, and the drains being proportionably deepened correspondent to this lower situation: this would occasion so considerable a descent, as to run off the waters of the greatest downfalls as fast as they came down, vithout danger of overflowing any of the lower grounds, which might iometimes be the case, was the Clough continued at it's present height \*. - Let us now see what fall will be obtained, upon a supposition that the Clough sloor was lowered 3 feet.

to the prefent Charles	1 .	317+
The whole fall from the fouth end of the moors contiguous to Green Bank, to the prefent Changle	5	9
And the Clarge floor being lowered 3 flet, would make,	ô	9
The diffance by the courie of the drainsoft nightened, according to the letters  A B C D E F is, will be not quite, but near upon five niles, and fampoing we allow a defect of a foot per mile, which is very ample and indicate for any purposes of drainage, the whole differt would be,  And allowing for the thickness of water going over the floor,		
Sum to be taken from the whole fall,	5	6
Remains the quantity that the water will be reduced wishin foll, at the most remate low places,	3	3

\* N. B. This would be prevented by gates being prefled, as mentioned in my former Peport. N. 3. Dd Vot. L

N. B. This is a foot 3 inches more than necessary, and will be more at all	nearer	distances,	as fu	rther
appears thus:	Ft.	In.	Ft.	In.
The fall from Haldenly Common to the Clough floor, if laid 3 feet lower, will be	-	-	7	2
The descent for 3 miles 21 furlongs, at 1 foot per mile, will be	3	3 1/4		
The water over the floor,	0	6		
The fum deduct from the whole,		~ .	3	91
And there remains for the reduction of the water within foil at Haldenby Common,	-	-	3	41

Hence it appears, that was Hackensyke Clough floor laid lower by 3 feet, and the drains properly adapted thereto, that it would be as effectual as could be defired.

It next comes in place to enquire, whether new drains in a different direction, and to a different out-fall, may not be more eligible than the former; and from inspection of the country it appears, that the natural course of drainage tends from Haldenby Common towards Trent Fall, which is undoubtedly the lowest ground; and it also appears from the levels that there is a greater fall thither than to the Ouse at Hackensyke, by  $\mathbb{I}$  foot  $7\frac{1}{2}$  inches; it also appears by the plan, that the distance, according to the course of the new proposed drain, abcdef gb, is rather more than  $5\frac{1}{4}$  miles, which is somewhat more than  $\frac{1}{4}$  of a mile more than the former, which in this case is inconsiderable: if therefore the drainage to Hackensyke Clough is as compleat as can be required, when laid 3 seet lower than at present, it will be still more unexceptionable when laid at the same depth at Trent Fall, for as it will then lay  $\mathbb{I}$  foot 8 inches above low-water mark, it will run a greater length of time at each tide, and therefore the drains, after making proper allowance for the difference of distance, may be of less width than would be required at Hackensyke to be of equal effect.

The falls will then stand as follows:

From the surface of the moors north of Green Bank, to the floor of the sluice at Trent	Fall, laid	Ft.	In.
3 feet below that now at Hackenfyke,	-	8	9
Fe	. In.		
Thickness of water over the floor,	6		
Fall of the water 5 miles, at 1 foot per mile, 5	3		
The sum to be deducted from the whole,	-	5	9
Leaves for the reduction of the water within foil at Green Bank,	-	3	0
Again. From the surface of the land of Haldenby Common to the floor of the fluice at T	rent Fall,	7	2
Thickness of water over the floor,	6		
Fall of the water according the course a b c d e f g, 3 1 miles, at 1 foot per mile,	3 6		
The fum to be deducted from the whole,		4	0
Remains the reduction of water within foil at the lowest part of Huldenby Common,		3	This

This reduction would drain even Plumb Groves and Robinson Deeps, was it not advisable to referve those undrained for watering cattle, for which purpose it will also be necessary to have land-doors to the outsall clough or sluice, to pen the water at dry seasons, and also at some other places; but those will be private works it will be needless to insist thereupon. The proper widths, depths and dimensions of the drains and sluice are contained in the following Estimate. The course relative to Trent Fall are coloured yellow, those to Hackensyke red.

This level is very well circumstanced with respect to barrier banks. The only ones that appear necessary to be repaired, on account of the general undertaking, is the south wing of Green Bank and New Bank, the particulars of which are contained in the Estimate. I find the marks lest by the floods last winter, upon the south side of the Green Bank, to be 3 feet 11 inches above the surface of the lowest grounds there, that is, 6 feet 10 inches above the lowest grounds of Haldenby; and as this body of water was brought hither by a general overslowing of the level of Hatseld Chace, occasioned by the breaking of the banks of the river Idle, it would in consequence have laid almost the whole tract now under consideration under water, if it had sailed. It therefore plainly appears that this bank should not only be continued as a barrier, but strengthened and prolonged, as specified in the Estimate, for the safety of all the lands laying north thereof.

It comes now under consideration how far the drainage of the land of Eastoft south of Green Bank, into the drains proposed for this level north of Green Bank, can be complied with, with safety to the latter: and I am of opinion it may be done with perfect safety, provided the communication through Green Bank be made by a tunnel not more than 10 inches square, with so shuttle or stop sluice thereupon; for had such a tunnel been open and running during the flood of last winter, had also the drains and outfall clough, specified in the following Estimate, been then made, I am of opinion it would have been carried off as fast as it was uttered, without overslowing the level. But to take away all scruple, I would propose to lay the running of this tunnel under the sollowing restrictions.

1st. It shall always be kept shut whenever the grounds to be drained thereby are over-slowed by the waters from Hatsield Chace, or any other foreign waters, overtopping it's barrier banks, and to continue shut so long as the water thereupon has any communication with any such foreign waters.

N. B. This is a foot 3 inches more than necessary, and will be more at all appears thus:	nearer Ft.	distances,	as fur Ft.	ther In.
The fall from Haldenly Common to the Clough floor, if laid 3 feet lower, will be The descent for 3 miles $z_{\pm}^{1}$ furlongs, at 1 foot per mile, will be The water over the floor.	3 0	3 <sup>3</sup> / <sub>4</sub> 6	7	2
The sum deduct from the whole,	-	-	3	9 <sup>2</sup> / <sub>4</sub>

Hence it appears, that was Hackensyke Clough floor laid lower by 3 feet, and the drains properly adapted thereto, that it would be as effectual as could be defired.

It next comes in place to enquire, whether new drains in a different direction, and to a different out-fall, may not be more eligible than the former; and from inspection of the country it appears, that the natural course of drainage tends from Haldenby Common towards Trent Fall, which is undoubtedly the lowest ground; and it also appears from the levels that there is a greater fall thither than to the Ouse at Hackensyke, by 1 soot  $7\frac{1}{2}$  inches; it also appears by the plan, that the distance, according to the course of the new proposed drain, abcdef f g b, is rather more than  $5\frac{1}{4}$  miles, which is somewhat more than  $\frac{1}{4}$  of a mile more than the former, which in this case is inconsiderable: if therefore the drainage to Hackensyke Clough is as compleat as can be required, when laid 3 seet lower than at present, it will be still more unexceptionable when laid at the same depth at Trent Fall, for as it will then lay 1 soot 8 inches above low-water mark, it will run a greater length of time at each tide, and therefore the drains, after making proper allowance for the difference of distance, may be of less width than would be required at Hackensyke to be of equal effect.

#### The falls will then stand as follows:

From the surface of the moors north of Green Bank, to the floor of the sluice at Tr	ent Fal	7, laid	Ft	In-
3 feet below that now at Hackensphe,	-	-	8	9
	Ft.	In.		
Thickness of water over the floor,	Q	6		
Fall of the water 5 4 miles, at 1 foot per mile,	5	3		
The sum to be deducted from the whole,	44	-	5	9
Leaves for the reduction of the water within soil at Green Bank,	-	-	3	
Again. From the surface of the land of Haldenby Common to the floor of the fluice	at Tren	t Fall,	7	2
Thickness of water over the floor,	0	6		
Fall of the water according the course a b c d e f g, 3 \frac{1}{2} miles, at 1 foot per mile,	3	6		
The sum to be deducted from the whole,	-	-	4	0
Remains the reduction of water within foil at the lowest part of Haldenby Common,	-	•	3	This

This reduction would drain even Plumb Groves and Robinson Deeps, was it not advisable to reserve those undrained for watering cattle, for which purpose it will also be necessary to have land-doors to the outsall clough or sluice, to pen the water at dry seasons, and also at some other places; but as those will be private works it will be needless to insist thereupon. The proper widths, depths and dimensions of the drains and sluice are contained in the following Estimate. The course relative to Trent Fall are coloured yellow, those to Hackensyke red.

This level is very well circumstanced with respect to barrier banks. The only ones that appear necessary to be repaired, on account of the general undertaking, is the south wing of Green Bank and New Bank, the particulars of which are contained in the Estimate. I find the marks lest by the floods last winter, upon the south side of the Green Bank, to be 3 feet 11 inches above the surface of the lowest grounds there, that is, 6 feet 10 inches above the lowest grounds of Haldenby; and as this body of water was brought hither by general overslowing of the level of Hatsield Chace, occasioned by the breaking of the banks of the river Idle, it would in consequence have laid almost the whole tract now under consideration under water, if it had failed. It therefore plainly appears that this bank should not only be continued as a barrier, but strengthened and prolonged, as specified in the Estimate, for the safety of all the lands laying north thereof.

It comes now under consideration how far the drainage of the land of Eastost south of Green Bank, into the drains proposed for this level north of Green Bank, can be complied with, with safety to the latter: and I am of opinion it may be done with perfect safety, provided the communication through Green Bank be made by a tunnel not more than 10 inches square, with I shuttle or stop sluice thereupon; for had such a tunnel been open and running during the stood of last winter, had also the drains and outsall clough, specified in the following Estimate, been then made, I am of opinion it would have been carried off as fast as it was uttered, without overslowing the level. But to take away all scruple, I would propose to lay the running of this tunnel under the sollowing restrictions.

1st. It shall always be kept shut whenever the grounds to be drained thereby are overshowed by the waters from Hatfield Chace, or any other foreign waters, overtopping it's barrier banks, and to continue shut so long as the water thereupon has any communication with any such foreign waters. 2dly. That it shall be kept shut at all other times, when the water in the mother drain rises within 9 inches of the surface of the low part of Haldenby Common, or within 6 inches of the general surface of the lands laying north of Green Bank, which may be ascertained by setting up stones or marks for that purpose.

The continuing of the barrier of this part of Eastost beyond the limits specified in the Estimate, the internal drains, erections, and maintenance of the tunnel of communication, I look upon to be private works, respecting this part of Eastost Lordship, and therefore not comprized in the Estimate; and as this scheme proposes nothing more than the carrying the mother drain to the boundary of each Lordship, so as to give the waters thereof a proper outsall, all other drains and internal works are considered as private works, and to be done at the particular expence of the respective proprietors.

ESTIMATE for a Drainage, by a new course, to Trent Fall. The stoor of the stuice to lay 3 feet lower than the stoor of the present Clough at Heckensyke, that is, about 1 foot 8 inches above low water at Trent Fall; the stuice to be 10 feet water-way, the drain to be 10 feet bottom, to rise from the Clough towards Green Bank, which will be at the rate of 10 inches per mile.

	t.	J.	da
To digging the pit for the clough or sluice, 19 feet deep, 35 feet mean width, and			
150 feet mean length, containing 2463 cube yards, at 4d	41	1	0
To 91 yards in leagth, from the Trent to a, exclusive of the fluice pit, 15 feet deep,			
15 feet bottom, 50 feet top, contiining 4700 yards, at 3d	58	15	0
From thence to b, 387 yards, 12 feet deep, 10 feet bottom, 42 feet top, containing			
13416 yards, at 3d		14	0
From thence to Higgard's Lane, the end of Long Dyke Bank, at c, being in length			
1150 yards, being 10 feet bottom, 36 feet 8 inches top, and at a medium 10 feet			
3 inches deep, containing 35796 cube yards, at 3%.	- 1	19	0
From thence through the rising ground of Adling ficer, by the fide of Long Dyke Bank, to d,			
length 550 yards, 10 feet bottom, 36 feet top, 2nd mean depth 9 feet 7 inches,			
wintaining 13628 yards, at 3d		7	0
From thence to the north end of William Bank, e, 2550 yards long, to feet bottom,			
2) feet mean width at top, and 8 feet 1 inch mean depth, containing 44989 yards,			. 7
at 2 1 d	408	12	8 ½
From thence to Green Bank, by the letters of g h, being in length 5496 yards, at			
a medium 8 feet bottom, 18 3 feet top, and 5 5 feet deep, containing 42234 yards, at 2 d.		19	0
To making the branch drain k, l, for communicating the waters of Whitgift low grounds			
with the main drain, being 690 yards long, 5 feet bottom, 13 feet top, and 4 feet deep,			
contining 2760 yards, at 1 gd.	17	5	0
Carried Communic	1660	12	18

Carried forwards, 1660 12 %

					L.	f.	ď.	
Brou To repairing and floorgthening M. w Land, by way of a bar	glat forwards, rrier, to defen				1660	12	8	
against Rechey's Common, so as to have 12 seet base, 4								
taining 2500 yards in length, and in the whole 8889 yar					55	11	T.	1/2
To repairing and heightening Green Bank, from the elbow 2 yard, per yard running at a medium, being 1260 yard								
at 2%					21	0	0	
To extending Go . Bank about 100 yards further fouth, for	as to render	the fan	e effe	:Etual,				
to be 12 feet leat, 4 feet top, and 4 feet high, containing	g 355 yards,	at 1 ½	d.	-	2	4	4	<u>-</u>
Spa	ide work		-	£	1739	8	2	1 2
Buildin	<u></u>							
To build tog a mer. Thier, of brick with flone facing, at	The state of the s	he r	o feet	clear				
with a way, including temporary dams, drainage of w	ater, filling fi	n the g	round	d, and				
openi g the fluice		-		-	500	0	0	
For a road bridge, of brick, at Hoggard's Lane		-	-		40	0	(	)
To a ditto at Cow Pasture Lane -			-	-	30	0		5
To a bridge for cause, the middle of Haldenby Common		-		-	15	0		0
The a rougher land, it road leading to Whinfgate Bank					30	Ç		
To a castle-lably a over the main drain, to communicate the	e two parts of	f Oujeja	eet Go	mmon,	10			0
To a ditto, over the branch drain		•		-	5		,	0
Bu	ilding -		-		£.630	o		0
Abstra	ıct.							
					1739		3	2 5
Spade work			_		630		0	0
Supervising and contingencies, at 10 l. per cent.	~	-		-	237		0	0
Sapervining and contingenties, at 1997 per			Ti ota		f 2605		8	2.5
			I Cta	· ·	£, 2605			
The quantity of land used	I in this un	dertal	ing					
THE directly of faute dies			Cut.			Co	vere	d.
		$A_{t}$	R.	$P_{\uparrow}$		1.	R.	P.
In Adling fleet, Trentfield, and high grounds from Trent to	point d,	5	3	10		I	2	32
1 the few love ground, from d to to		5	0	16		2	0	32
William Bank from e to f, there being space enough for the	is cut .			16		4	2	32
From t to m. nevols Habitaly Gammon -		2	1	0		r S	0	0
Through One are Stor, Sec. from m to b, at Gran bar	1k -	+	2	20		1	1	a
The branch drain to Whitespi Mear, from & to i,	-		-					
•	e	17	3	28		37	3	16
				_				

2dly. That it shall be kept shut at all other times, when the water in the mother drain rises within 9 inches of the surface of the low part of Haldenby Common, or within 6 inches of the general surface of the lands laying north of Green Bank, which may be ascertained by setting up stones or marks for that purpose.

The continuing of the barrier of this part of Eastost beyond the limits specified in the Estimate, the internal drains, crections, and maintenance of the tunnel of communication, I look upon to be private works, respecting this part of Eastost Lordship, and therefore not comprized in the Estimate; and as this scheme proposes nothing more than the carrying the mother drain to the boundary of each Lordship, so as to give the waters thereof a proper outsail, all other drains and internal works are considered as private works, and to be done at the particular expence of the respective proprietors.

ESTIMATE for a Drainage, by a new course, to Trent Fall. The stoor of the sluice to lay 3 feet lower than the sloor of the present Clough at Hackensyke, that is, about 1 soot 8 inches above low water at Trent Fall; the sluice to be 10 feet water-way, the drain to be 10 feet bottom, to rise from the Clough towards Green Bank, which will be at the rate of 10 inches per mile.

	£.	J.	d.
To digging the pit fir the clough or fluice, 19 feet deep, 35 feet mean width, and			
100 feet mean length, containing 2463 cube yards, at 44	41	1	0
To 94 yards in hoger, from the Treat to a, exclusive of the fluide pit, 15 feet deep,			
10 feet bottom, 50 feet top, containing 4700 yards, at 3 d	58	15	0
From thence to b, 387 yards, 12 feet deep, 40 feet bottom, 42 feet top, containing			
13416 yards, at 3d	167	14	0
From thence to Heggara's Lane, the end of Long Dyke Bank, at c, being in length			
1150 yards, being 10 feet bottom, 36 feet 8 inches top, and at a medium 10 feet			
3 inches deep, containing 32796 cube yards, at 3d.	384	19	0
. From thence through the rising ground of Addingficet, by the fide of Long Dyke Bank, to d,			
length 550 yards, 10 feet bottom, 36 feet top, and mean depth 9 feet 7 inches,			
4 outaining 13628 yards, at 3 d	170	7	0
From thence to the north end of William Bank, c, 2550 yards long, to feet bottom,			
29 feet mean width at top, and 8 feet 1 inch mean depth, containing 44989 yards,			
at 2 ½ d	468	1.2	8 7
From thence to Green Bank, by the letters of g b, being in length 5496 yards, at			
a medium 8 feet bottom, 18 feet top, and 5 feet deep, containing 42234 yards, at 2 d.	351	19	0
To making the branch drain k, l, for communicating the waters of Whitgift low grounds			
with the main Frain, being 690 yards long, 5 feet bottom, 13 feet top, and 4 feet deep,			
Contining 2760 pards, at 1 & d.	17	5	0
C = 1-2 C = = 1.	.61.	7.0	81

Carried forwards, 1660 12 03

					£.	5.	d.	
To repairing and flrengthening New Bond, by way of	Brought forwards a barrier, to def				1660	12	8 }	
against Reedress Common, so as to have 12 feet be taining 2500 yards in length, and in the whole 882. To repairing and heightening Green Bunk, from the cay yards per part running at a medium, being 1260.	ife, 4 feet top, an 89 yards, at 1½4. albow fouthward,	nd 4 feet - with an	high, additi	con- - on of	55	11	1	2
			- , -0	jaine	21	0	0	
To extending $G_t \mapsto Bank$ about 100 yards further for to be 10 feet leat, 4 feet top, and 4 feet high, cor				ectual,	2	4	4	7.
	Spade work		-	£	. 1739	8	2	Ž.
Bu	illing.							
To built in care duice, of brick with flow facing		to he i	to fee	t clear				
with a say, including temporary dams, drainage	of water, filling	in the	groun	d, and				
opening the fluide				-	500	0	C	>
For a road builge, of brick, at Hoggard's Lane		-		,	40	0	(	
To a ditto at Cow Passure Lane -		-	-	-	30	0	(	0
To a bridge for cause, the middle of Haldenty Com	7/40/4 =	-		-	15	0		0
The a completion of the road Lading to William the	Bank -	-	-		30	C		0
To a carthe-hide a over the main drain, to communi	cate the two parts	of Ouje	fleet C	ommon,	10	0		0
To a ditto, over the branch drain				-	5	C	,	0
	Euilding -		-		£.630	0		0
Δ	bstract.							
A1	- LOILLACC		_		1739		3	2.5
Spade work		_	_		630		0	0
Building -	•			_	237		0	0
Supervilling and contingencies, at 10 l. per cent.	*							
			Tota	l,	L. 2605		8	25
		,	1.1					
The quantity of land	l used in this v	inderta	King			0		1
			Citt.				zete n	1. P.
		A.	R.	P.			R.	32
In Adding fleet, Trentfield, and high grounds from I	rent to point de	5	3	16		10	0	32
12 . C. Alan ground, from d to to	-	- 5	0	10		2	0	3-
Will to Bank from t to f, there being space enough	for the cat.		Ī	16		3	2	32
From the st never Haldenby Comme	T	. 2	1			S	0	0
Through Onto act Mon, Sec. from m to b, at Gre	en Bank -	4	0	0		1	1	3
The branch drain to Whitehyt Mear, from k to is		0		20				
	e	.17	3	28		37	3	16
		-						

# Abstract of the Estimate by way of Hackensyke.

The drainage by Hackensyke being estimated in the same particular manner, and the main drain being made 11 feet bottom, to the point B, near Coat's Bridge, in order to be an equivalent to the greatest length of time of running at Trent Fall; and being made from thence in two branches, one along the course C, D, E, F, h, which will drain Ousesteet, Whitgift, and part of Eastoft, and the other by the course B, G, H, I, e, f. which will drain Adling fleet, Fockenby, and Haldenby, and also a second branch from C. by the Folly to Bought Gate, to make a proper out-fall for East oft waters.

															L.	J.	d.
The Spade Work		-		-		-		-		•		-			1833	4	0.1
Building -	-		-		-		-		-		•	4	-		645		0
Contingencies, at	10 per	cent.		-		-		-		-		-			248	0	0
														-			
											Т	otal,		L.	2726	4	Q
								pt.									

#### Land used in this Undertaking.

					C	lut.		Covered.				
					A.	R.	P.	$A_{\gamma}$	R.	P.		
From Ouje to A,	-	-	•	-	1	1 1	2	2	2	24		
From A to C,		-	-	•	8	0 3	35	16	I	30		
From C to Green Bank -	•	-	-	-	3	1 2	:0	6	3	0		
From B to e -					2	1 2	10	4	3	0		
Willow Bank, e to f, land enoug	h for a cut,	•	-	-	-			2	0	0		
Branch from C to Bought Gate	-	-	-	-	1	0	0	2	0	0		
							-					
					16	1	7	34	2	14		
							-					

N. B. If Hackensyke Clough was made use of, as long as it will stand in it's present form, and the drains dug of a proper width to admit of their being carried to a proper depth, when that Clough shall be obliged to be rebuilt on account of repairs, and lowered to the proposed depth,

- "														L.	I.	d.
The Spade Work w	ill then	come to		-	-		-		-		, e		-	1691	3	10
The Building to	-	-	•			••		-		-		*		145	0	0
Contingencies to	-	-		_	-		-		-		_		-	183	12	0
_																
														£. 2019	15	10
															_	

And in ease Ousesteet Clough was to remain as it does, without intention of lowering the same, the expence of proper drains, &c. suitable thereto, would amount to 16361. 5s. 01d.

J. SMEATON.

## Austhorpe, December 3, 1764.

#### DRIFFIELD BECK CANAL.

ESTIMATE for making a navigable Canal from Driffield Beck to a place called the Townsend, near Skerne, to be 16 feet at bottom, and 4 feet deep of water, with batters or flopes according to the nature of the ground.

with patters of hopes according to the nature of the glound.			
ROM Driffield Beck to the beginning of Lewcop pasture, being 15% chains length, mean depth 6 sect 5 inches, batters 1 to 1, the mean width at top will be 28 feet 9 inches, con-	£.	5. 6	ž.
trining case yards, at ed	45	5	6
the batters as 3 to 32, the mean width at top will be 34 feet 9 inches, the folid contents	76	9	9
rom the low corner of the Helmes to 19.6 chains up the same to the point 1 in the map, mean depth will be 11 seet 8; inches, and being of a marly nature, the batters as 3 to 4, the mean width at top will be 47 seet 2 inches, the solid contents 17712 yards, which being			
hard to dig may come to 4 d.	295	4	-
Cutting to the middle of the Holmes,	416	19	3-
a land a 28 feet horitom, for no varies at the near, to as to take a			
breadth and 3 in length, for convenience of unloading at warehours, being dist	16	13	4
feet deep, To drainage of water, supervising, and contingencies,	60	0	0.
To the middle of the Holmes,	493	12	7
From the middle of the Holmes, to the Townsend, upon a dead lev	rel.		
To carrying on the cut from the middle of the Holmes to the top of the Pighill at P, being			
being 31.10 chains long and 18 feet mean deputy the same	1026	0	0
baing 22.5 Chains (Chem) mount appear	1105	16	3
the top width will be 72 feet, and the folid contents 53079 yards, at 5 d.	2131	16	3
	-		
ESTIMATE for carrying the navigation to the Townsend by a l	ock.		
- "	410	5 19	) 3
To the middle of the Holmes, the cut as before,	600	a í	) (
'C Cont " " 1 Louis			

To cutting from thence to the top of Pighill 31.1 chains, at a medium 8 feet deep, batter

3 to 31, the top width will be 34 feet 9 inches, the folid contents 15443 yards, at 3d.

193 9 9

1210 9 9

Carried over

Brought forwards To cutting from top of Fighill to Townsend, being 23.5 chains, mean depth 11 feet, batters	1210		0
as 3 to 4, the width at top will be 45 feet 4 iaches, the folid contents 19399 yards, at 3.1. 1	282	18	C
To making the dock as before,		13	
To bringing the water over the moor, suppose	15	O	
To supervisal and contingencies,	150	0	0
Total	1675	0	4

PROFESSION OF THE PROPERTY. SAMESTING PROPERTY AND ADDRESS OF THE

# A DESCRIPTION of this plan, with a comparative calculation of its abilities with the prefent work, here follows:

1, 1, 1, &c. represent the different parts of the frame-work, 2, 2, 2, &c. the parts of the water-wheel; 3, 3 its starts, of which more hereaster; 4 the main shafts ends; 5, 5 the parts of the spur-wheel; 6 the wallowers; 7 the crank; 8 the crank rod; which communicates with the sub regulator; 9 and 10 the communicating rod between; 9 the sub, and 11 the top regulator; 12, 12 the arch heads to the top regulator, to enable the buckets to make a perpendicular stroke, thereby enabling them to last much longer, go leoser leathered, which will chamber or wear the barrels less, and lose less water. B. B. The chains to the bucket or piston rods; 14, 14 the bucket rods; 15 the bucket at the end of its rod in the section of the engine; 16, 16 and 17, 17 the sace view of an engine together.

Now whereas the circumstances attending these works, being almost peculiar to themselves; it requires, in order to render them more essectious and serviceable, a particular or peculiar application; for though there are many stream and current mile, yet they go with a much more uniform motion, having nearly a certain quantity of back water, or strength of current; but as both these articles are so varying at these works, it requires a varying application of machinery, which is performed as softows: supposing the wheel to be at work with the greatest strength of tide, and going three turns per minute, then the sub-regular to 9 has its subtrum or center of motion at a, which being 12 feet distance from b, where the crank rod lists 2 feet 6 inches, and b being 6 feet form c in the sub-d in the sub-regulator, both lists 2 feet 9 inches; and as d is 10 feet distant from its center of a ction c, and 3 feet from f, the chains center, and that of the barrel, therefore it makes 4 10 stroke in the barrel; and when the wheels are at work with a great or water, and move at a flow rate, yet there is the sufficient momentum or

THENNE AN ARTHU

vot 1 p.

force to raise much water; that force being always as the quantity of water multiplied into the velocity, so that if there be three times the depth in water, and but one third of the velocity, that is, at the strength of the tide, nearly as much water may be raised as at strength of tide, in order to attain which, it is necessary the engines should make a stroke proportionably longer, as they move fewer times, which will be obtained by moving the center of motion a to a a, then as a a will be 5 feet 6 inches from b, upon the crank-rod lifts 2 feet 6 inches, and b being 6 feet from c, therefore c and d in the top regulator are both listed 5 feet  $2\frac{3}{4}$  inches, and f the chain, and, consequently, the rod 6 feet to  $\frac{1}{2}$ , which is such a stroke made in the engine, which compensates in a great measure for the slowness of motion in the wheel; and all this is done in the most simple and lasting manner, by the application g at the end of the sub-regulator g.

Now the comparative quantity of water raised by the present, and what might be raised, are as follows.

Having considered that though there are rules in mechanics for finding the quantity of water passing by in a given time, in a given section, by knowing the height of the water, but as that is very difficult but where the back water is very inconfiderable, and that the velocity of the water at its surface might be obtained, I rejected both in this case, and noted, that the three-ring wheel, at the strongest working, has gone 6 turns per minute, which is nearly 25 feet diameter, and the new wheel in the same time made  $5\frac{1}{2}$ turns per minute, which is nearly 30 feet diameter; the whole space passed through in the minute, by each wheel, being 495 feet, this, with their charge of work on them, which must impede the water's motion at least 1/4; therefore, if neither had been doing work, the water, by going 4 quicker, would have passed through a space of 619 feet per minute, which multiplied into 5 feet, which is about the depth the wheels go the strongest at, and the product in 12 feet from the width, gives 37140 cubic feet of water expended on the wheel per minute, which is 3612 hogsheads; now as the wheels revolution vary as  $6\frac{2}{3}$  to  $5\frac{1}{2}$ , therefore the quantities raised must vary in like proportion, that I will reason upon the greatest quantities raised, which is 151 hogsheads per minute. Now as the difference or head of water is obtained by knowing the water's velocity, and that being known as above to be 619 feet per minute, it refults that the acting head to produce that must be 2 feet nearly; and I will suppose that the average height of all the water then raised by the sour engines on the wheel did amount to 100 feet, that is what some part of it might be raised higher, other like part discharged as much lower, and 2s 2 feet, the acting head, is contained five times in the height, we will suppose each logshead to be one pound; then suppose 3612lb. (or hogsheads) expended on the E e Vol. I.

wheel each minute, to be laid upon one end of a lever at I foot distance from the center, it is evident it would keep in equilibrio 72 lb. at the other end, which is fun. posed to be 50lb. on the other side of the center, which 72 should be the number of hogsheads of water the wheel should keep suspended on the engines, it being the 50th part of the water expended, and fluids act in relifting in this kind as solids, on levers: but to allow amply for friction, &c. and to give the part of the machine sufficient motion, I will suppose, that nearly ; of the 72 might be raised, (for in good machines, under favourable circumstances, 3 of the 72, or 54 hogsheads, might be raised) which will be 24, and, according to my expectation, something more than that quantity, viz. 27 hogsheads per minute, for and by the following reasons: as the wheels floats are now no more than from 15 to 24 inches wide, they can produce no greater effect by their resistance than in proportion to their surface, for all the water that might be acting against them, extra to their present dimensions, goes over, rather to the impediment of the wheel than not, whereas was this width increased, the power of the wheel would be increased likewise to a certain measure, but not if the other parts remained the same as now, for as the wheels go now nearly the same pace as the water, therefore it is necessary to stacken the wheels motion, and increase the engines strokes, to refift the running water more, and thereby a proportionably greater quantity of water would be raised: then the starts 3.3, should be thus constructed; they should all stand out 3 feet from the ring, each other having the boards only up to the ring, as may be seen by inspection, and the others having the boards within to 5 seet from the starts end, as shewn: the method for doing them cheapest, most lasting, and ferviceable, is to make the starts pretty wide, cut I slit in the middle, and slip the boards down it, and the whole is secured with a small bolt in the short, and two in the long ones, without iron plates; and up against each arm of the water-wheel to put boards 6 feet from the starts end, by this method the wheel will be impeded getting into water less than if the starts were all 5 seet long, and the boards as broad, and nearly the same effect produced.

Now by this provision, the wheel, when going so slow as 3 turns per minute, will so refift the water as to give it an opportunity to act fo powerfully as to work 6 engines of seven-inch barrels in this manner at strength of tide, 3 turns the wheel, the wallowers going 3 to the wheels 1 makes 9, and the sub-regulator moving on the center a, will produce 4 feet 101 inches stroke, which multiplied into the 24 barrels will produce 27 hogsheads nearly per minute; and in less strength of tide, for some time before and after high water, the wheels will go from 1 to 2 turns per minute, by means of the large surface of floats, I will call it 11 turns, and then the sub-regulator will move on the

center a a, which will produce 6 feet 101 inches stroke in the engine barrels, and that in the 24 barrels will give 19 hogsheads per minute.

3 rings at	This design at	Ditto at 1 5
6½ turns	3 turns to rife	6 feet to 1 inches stroke,
rise 15 hogsheads	with 4 feet 10 ! inches stroke,	19 hogsheads per
per minute.	27 hogsheads per minute.	minute.

The following is an examination of the faid engine, in answer to the above.

Examination by John Smeaton of a delign for a Water-Engine, communicated by Dr. Birch.

This design, though not so mentioned, appears evidently intended for London Bridge water-works, and therefore as such I shall consider it; and though the unknown inventor of the defign has shewn evident marks of genius, and a laudable attempt of improvement, yet as I cannot agree with him in the whole of his reasoning about it, I think it necessary to give my opinion with that freedom that becomes me in a matter wherein I am confulted, and therefore have a right to expect that what I may say will not be considered as the essects of a desire to criticise, but to do justice, where my opinion is desired in the way of my profession.

In the first place, I agree with the inventor in the use of arches and chains at the end of the regulator, having ordered the like in the engine lately erected for the West Ham Company at Stratford.

2d. I also agree with him in thinking the circumstances of these works are so peculiar to themselves as to require peculiar applications, in order to bring them to persection, and that it is to be wished that means could be found out by which the load could be occasionally varied, in proportion to the variations of velocity and power, without rendering the engines complex, and more liable to be out of order. I also agree with him, that by means of a moveable center, to what he calls a sub-regulator, the stroke of the engine may be varied, and therefore the power of the engine in the same proportion; but I can by no means agree with him in the use to be made of this machinery; he supposes that when the tide is high, and the current moves slow, that the body of water being then great, the superior quantity will be equivalent to the want of velocity, fo that if there be 3 times the depth in water, and but \frac{1}{3} of the velocity, that is at the strength of tide, nearly as much water may there be raifed, as at the strength of tide.

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3 rings at	This defign at	Ditto at 1 1
6 2 turns	3 turns to rife	6 feet to 1 inches stroke,
rife 15 hogsheads	with 4 feet 10 1 inches stroke,	19 hogsheads per
per minute.	27 hogsheads per minute.	minate.

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But had the inventor computed the head or acting column of water necessary to produce i of the velocity, by the same rules that he finds 2 feet necessary to produce the velocity of 619 feet per minute, he would have found i of 619, viz. 206 feet per minute, produceable by a head or column 23 inches, which is only 5 of 2 feet, it being well known that the square of the head is as the velocity. Hence it appears, that as the acting column is only ; of the height, the impulse or pressure upon the same quantity of surface of float-board will be ; also; and even if we suppose the surface acted upon to be increased in proportion to the depth of water, which is not the case, (in the construction before me) the whole impuse or pressure upon the wheel can be only of what it would be at strength of tide; so that if the wheel is loaded as here proposed, near high water more than at strength of tide, in the proportion of 4 feet 101 inches to 6 feet 10½ inches, which is as 5 to 7 nearly, it is very probable that the wheel. instead of doing nearly as much as at the strength of tide, would stand quite still, and the benefit of the flow motion, that would otherwise take place, quite lost: in short, it is like a horse moving slow with his load in consequence of having carried it far, and being wearied therewith, to load him harder in order that the greater burthen may compensate for the slowness of his motion. It therefore plainly appears, that if any good is to be expected from this fliding motion, it must be by adjusting the longest stroke to the strength of tide, that as the tide grows weaker the stroke may be shortened, and the power of the engine adapted to the power to move it.

In regard to the machinery of the sliding center, as it is not perfectly made out, I am enabled to fay the less upon it; but in an engine that works both ways, that is, lists up as much as it pulls down, any shake in the center work will be very detrimental to its motion, and occasion it to be frequently out of order; and further I conceive it difficult so to contrive it as to be, and keep lastingly steady, especially as in the present engine, in some cases, the action of the crank upon the center will be greater than its action upon the piston, as 11 to 4; but supposing the difficulties in the execution to be conquered, still this must happen, that as the barrels in moderate space of time will sensibly chamber, and the middle part of the barrel, so far as the short stroke reaches, will be always in wear, but that part above and below the limits of the short strokes only in wear when the long stroke is used, it follows that the barrels will chamber unequally. An engine will go very well with its barrel a good deal chambered; in short, they are seldom rebored so long as a new leathered piston can be got in at the mouth so as to fill in the chambered part, but then as they chamber nearly equal, and the stroke remains the same, that of the barrel in which the piston moves is still nearly a cylinder; but, in the case of unequal strokes, the piston would be obliged to move through a space alternately narrower and wider, which would cause it to work very hard.

Again

Again, as it might be sometimes for some days together in neap tides that the long stroke would not be made use of, the extra parts in that time would in iron barrels grow rusty, and when used again would not only cause the engine to go still harder, but also destroy the leathers. This last inconvenience would indeed be remedied by brass barrels; but where the charge and difficulty is great, and the effect not greatly superior, an invention so circumstanced is less eligible. This thought of altering an engine's power by a different length of stroke is not new to me, having had the same thought ten years ago; but while I was contriving the machinery necessary to perform it, the objection of the unequal chambering of the barrels occurred to me, which made me lay it aside, though cases have occurred to me in which it would otherwise have been applicable and useful.

It now comes in place to enquire into the general proportions and adjustments of the engine, to work at strength of tide; and I agree with the inventor, that a wheel of large diameter will wade in a great depth of water to more advantage than a moderate one; that a great breadth of float-board will resist the current more than a narrow one, and, consequently, give more power to the engine; and that the wheels, at strength of tide, may, with advantage, be made to move with a greater load than they do at prefent, but advantages carried to extremes often prove disadvantageous, according to the proverb, things in a middling way are frequently best.

With respect to the water wheel's height, that a wheel of 30 feet will get better through the water when wading at a given depth than one of 30 or 25 feet, is already allowed; but then as it moves proportionably flower, what is loft in number of revolutions of the first mover (in order that the same quantity of water may be raised) must be gained in the second; so that the same spur wheel will act on a less wallower, or a larger spur wheel acting upon the same wallower, produces a proportionably greater strain or twist upon the axis of the water-wheel; again, if more engines are put on, or with longer strokes, or both, the strain will be greater in proportion to the increase of water drawn thereby; if, therefore, the 25 feet wheel's axis goes 67 turns for the proposed wheel's 3, the strain upon the old axis to that of the new will be as 3 to 67, suppoling the same work done by both; but if the work done is more in the proportion of 15 to 27, the number of hogsheads supposed to be raised by each, or, as I calculated it, 13,2 to 26,7, the compound proportion will be 39,6 to 17,8, that is, the strain or twist upon the new wheel's axis, when at its lesser stroke, will be 41/2 times greater than that of the present 25 seet wheel; so that it is much to be questioned, whether an axis of 3 feet diameter, (which I apprehend to be that here proposed) or indeed any timber that can be got, will bear the strain so as to be sufficiently lasting.

The fize, disposition, and machinery of the floats I think is very good, but I think a smaller number would do as well in this situation: as to the fall proposed to the breast of the wheel, I think it not only expensive and difficult here to lay, but useless in this place on tide of ebb, and detrimental to the action of the wheel on tide of flood. The proposition of increasing the number of barrels I can by no means approve, for either another crank must be added, or there must be six barrels to each engine, either of which will be attended with inconveniencies, more complication, and more increase of friction than is necessary.

Lastly, with respect to the comparison of the effects of the old and new engine, I look upon it as a matter of certainty, from observation, that the 25 feet wheel moves  $6\frac{1}{3}$  revolutions at strength of tide, and, therefore, that its mean circumference moves through a space of 495, or, as I make it, of 497 feet, and, in this case, bona side raises 13 hogsheads of 63 ale gallons each per minute; but what is the velocity of the water driving the wheel, by no means appears, we are sure the natural velocity of the water must be greater than the wheel, but whether it be  $\frac{1}{8}$ ,  $\frac{1}{3}$ ,  $\frac{1}{3}$ , or  $\frac{11}{2}$ , by no means appears; the number 619 therefore, expressing the velocity of the water per minute, cannot be considered otherwise than as conjectural, and, consequently, the number 3612 hogsheads expended per minute, deduced therefrom, must be conjectural also: the acting head to produce 619 feet velocity is 1 foot 8 inches nearly, not two feet as here supposed; but if 619 is conjectural, the head 1 foot 8 inches must be also conjectural.

The mean height to which the water was supposed to be raised, viz. 100 feet, I apprehend is also conjectural, since it rises higher or lower in the stand-pipe, as there are a greater or less number of cocks open upon the mains: now if 100 be divided by 1 foot 8 inches, the quotient is 60; but as both the divisor and dividend are conjectural, the quotient will be still more so, and this being again a divisor to the conjectural number 3612, the quotient, which will be 60, will be still more conjectural; but supposing the number 619 and 100 both right, or nearly so, then the number of hogsheads equivalent to the power will be 60, but still there remains a disficulty what proportion of this quantity we must take for the neat performance of the engine; few or no engines that I have feen have yielded 3, most fall short of 1, and the prefent engine less than 5, but more than 5, that is, in case we are right in the two numbers before-mentioned, because if we are not, we still remain uncertain what the effect thereof is, in proportion to the power producing it. All, therefore, that we can fairly conclude is this, that a greater quantity of float-board will give a greater power, and a greater capacity of pumps will raise a greater quantity of water, provided we do not overload our power, or break our tackles by overstraining.

GASCOIGNE ON RAISING WATER OUT OF SHIPS.

EXAMINATION of Mr. GASCOIGNE'S proposals for raising water out of Ships. By John Smeaton.

RESPECTING that part of his proposal which consists in applying the forcing pumps to the raising of water out of the hold of a ship, by which means he is enabled to place the most essential parts of his machinery below the water line, is a merit that will be obvious to every scaman; I shall therefore not take up time in saying more about it than that it feems worth attending to, in case the conveniency of a ship will admit its execution, and the more especially as I am very certain, from experience, that as much water may be raifed in this way as any other. But in regard to the great preserence Mr. GASCOIGNE gives his pump above the chain pumps, in point of quantity delivered, and in point of power wherewith he proposes to work it, I can by no means agree with him. He proposes to raise 86 tons of water per hour to the height of 22 feet, by four men; whereas he gives us to understand, that the common chainpump requires 14 men to raise 60 tons per hour to the same height; a very surprising difference indeed! In order to prove this, he has recourse to calculation, and, as a ground-work, make this supposition, that four men will turn round the winch or handle of his machine 60 turns per minute, in which case, as this will produce a stroke of 1 soot long in four pump-barrels of 6 inches diameter each, this will necessarily produce a certain quantity of water per hour, which he calls 86 tons, but which, according to my computation, (supposing none-lost) is scarcely 84; but this I pass over: now if, on the other hand, we suppose that four men cannot turn round the winch 60 turns per minute, then the whole computation fails to the ground. He endeavours further to support himself by a comparison of the friction of his engine with the chain-pump; in order to this, he calculates the number of frictions in his machine, and gives each of them a determinate value, viz. four pounds; he also calculates the number of frictions in the chain-pump, and calls each of them five pounds; but as this is a method of computation totally new to me, and as he has given no fufficient reason why he calls a friction in one machine four pounds, and in the other five, nor why he might not as well have called them four ounces each, or 40 pounds, as best served his purpose, I shall not take up any more time in pursuing him any farther in this road, but shall endeavour to fet the whole in clear light.

Desagulters, in the fecond volume of his Experimental Philosophy, has taken good deal of pains in finding out a kind of land-marks to guide us in those kinds of pursuits, and to enable us to value the pretensions of projectors in the art of raising water, and he has told us, that the mean strength of a man, when applied to the best kind of pump that has been yet in use, amounts to no more than the raising one hogshead of water in a minute to the height of 10 feet; for my own part, I have made a variety of machines and many observations of this kind, but never yet found the value of mens strength at a medium equal to what is set down by Desagulters, unless they are supposed to work in haste, or distress, for a sew minutes; however, as it is more savourable to Mr. Gascoigne's proposal, we will for the present suppose the performance of men equal to what is stated by Desagulters, viz. one hogshead per minute at 10 feet high, that is, at the rate of 60 hogsheads per hour.

Now by the unalterable laws of hydrostaticks and mechanicks, if a man can only raise 60 hogsheads 10 seet high per hour, he can only raise 30 hogsheads to 20 seet, and only  $27\frac{3}{17}$  hogsheads to 22 seet in an hour, by the same rule of proportion. Now  $27\frac{3}{17}$  hogsheads, consisting of 54 ale gallons, as supposed by Desagulters, makes  $7\frac{1}{3}$  tons nearly, that can be raised by one man per hour, to the height of 22 seet, and consequently that  $28\frac{1}{2}$  tons per hour is the utmost that can be raised by 4 men, instead of which Mr. Gascoigne proposes to raise 86.

If we examine what he has stated concerning the chain-pump, by the same rule, we shall find its pretensions more modest: he supposes the chain-pump to raise 60 tons per hour by 14 men; now if 7th tons per hour is all that can be raised by one man to the height of 22 feet, 14 times 7 tons equal to 99 tons, or in round numbers 100 tons, is the utmost that can be raised by 14 men, instead of which the chain-pump only raises 60; so that here it falls considerably short of the mark. However, we may hence conclude, that as the chain-pump is deficient only 40 parts in 100, that all the pump-work that can be contrived will never exceed the prefent chain-pumps above the proportion of 60 to 100; whereas, men and quantity considered together, Mr. GASCOIGNE proposes to improve upon the chain-pumps in the proportion of 60 to 301, which is the number of tons that ought to be raised by 14 men, according to Mr. GASCOIGNE's method. For my own part, I believe that the friction naturally attending the chain-pump will never admit its performance to be quite equal to what can be done by other known kinds of pumps; but as it is capable of some improvement, I am clear that it might be made to raise 75 tons per hour instead of 60, and with more ease to the same hands.

It may perhaps be imagined that there is fomething in Mr. GASCOIGNE'S machine that is new, and preferable to all those that may be made trial of; but I beg leave to observe, that it differs in no effential point from the crank machines commonly made use of for raising water by water or horses for gentlemen's seats, brewers, distillers, dyers, &cc. though not that I know of applied to ships; and in point of raising water, I look upon it not quite so well adapted as the machine he describes, and calls the store-pump at Portsmouth, because a three-necked crank works more equably, and is attended with less friction than sour: and in regard to his application of an air vessel, though useful on many occasions, is of no use on the present; it must, however, be allowed, that the form of the pump in store at Portsmouth is much more cumbersome, and less adapted to the convenience of a ship, besides the inconvenience of some of its effential parts being above the water line. I apprehend Mr. GASCOIGNE's machine capable of some improvements, by which it might be made to raise about 80 tons an hour with 14 men, instead of raising 86 tons with sour men, and if its situation will be agreeable to the convenience of ships, may be used to a very good purpose.

London, January 20, 1765.

J. SMEATON.

Ff

# BRISTOL HARBOUR and CANAL.

PROPOSALS for laying the ships at the quay of Bristol constantly affoat. and for enlarging this part of the harbour by a new canal through Cannon's Marsh, by JOHN SMEATON.

of the 15 feet mark upon the lowermost marked staff upon the quay next the Avon, and clearing away 2 or 3 feet of the mud there laying, to make from 17 to 18 feet water.

N. B. The 15 feet mark is about 6 feet below the top of the quay, and about 4 feet below the spring-tide high water mark of the 24th and 25th of January, 1765, which, though not the largest, were nevertheless accounted considerable tides.

2dly. It is proposed to dig the new canal as far as the sluices, so deep as to make 18 feet water therein at the faid proposed level, and to make the same at least 100 feet wide in the clear.

3dly. To drop the tail of the new canal into the river Avon at the bottom of Cannon's Marsh, just above the Glass House.

4thly. To construct two separate sluices, one as near as conveniently can be to the river Aven, upon the tail of the canal, the other at the distance of 400 feet from the former, further within the canal; both these sluices to be furnished with two pair of pointing gates, one pair in each suice pointed to land, the other to seaward. The width of the chamber, or space intercepted between the two sluices, to be 60 feet, and the width of the fluices to be capable of taking in the largest ships that use the port, which I suppose will be done by an opening of 30 feet wide.

5thly. The threshold of the upper sluice to be laid at the depth of 18 feet below the constant water that is even with the bottom of the canal; but the floor of the chamber between the two sluices, as well as the threshold of the lower sluice, to be laid as low as the bottom of the river in the shallowest place, below the tail of the canal.

6thly. These things being executed as before mentioned, the present mouth or opening of the river Froome into the Avon to be stopped up by a solid dam of earth, furnished,

furnished, however, with such draw-hatches as may be necessary to assist the hatches in the gates of the fluices in discharging the freshes of the river Froome in rainy seasons, but yet so as to make a communication for all kinds of carriages from the Back and Quay down alongfide of the new canal between the same and the river.

7thly. The whole of the new work to be wharfed with stone, so as to form quays or fuch other conveniencies as shall be found necessary.

8thly. To erect draw-hatches at the new bridge at the head of the quay, capable of retaining the water behind them when the water in the new canal and quay is let off.

9thly. To have the command of the hatches, and to erect new ones, if necessary, upon the pond of Newgate Mill.

N. B. By the constructions above proposed, Tom's Dock and Bridwell Mill will be rendered useless, but Newgate Mill will be benefited thereby.

# OPERATION of the foregoing constructions.

When the tide is out, the water of the canal is proposed to be retained by the landgates of the upper fluice, all the rest being open on tide of flood. As the vessels come up, they go into the chamber between the fluices, where they always find equal water with that they came up with, which chamber is capable of holding eight ships, or four ships and six troughs, at the same time; here they wait at spring tides till the slood in the chamber is upon a level with the canal, at which time the sea-gates of the lower fluice are put to, which prevents the tide's water flowing into the canal; the land-gates of the upper sluice are then opened, and the vessels proceed to their births.

Then the large vessels that are going down, that require to depart at high water, are brought down into the chamber while the tide is flowing; the fea-gates of the upper fluice being then put to, and the hatches of the sea-gates of the lower fluice drawn, the chamber fills to the level of the tide in the river, and the sea-gates of the lower fluice are opened; and if any deep veffels are arrived after the tide had role to the level of the canal, they may now be taken in, where they wait all together till high water, when the outward bound depart, with the first moment of the ebb, and the inward bound wait till the tide has funk to the level of the canal; at which time the land-gates of the lower fluice are put to, and the sea-gates of the upper sluice are opened, which gives those ships leave to go to their births, and at the same time to take in such of the vessels as are outward bound, and can go down with the remainder of the ebb, after the water is fallen to the level of the canal; which vessels being brought into the chamber, the land-gates of the upper sluice are put to, and the hatches of the land-gates of the lower sluice drawn, by which means the water in the chamber is reduced to the level of the tide in the river; the land-gates of the lower sluice are then opened, and the vessels depart, leaving the sluice in the same position as we found it.

Hence it appears, that two fets of veffels may go up and two down in one tide, when the spring tides rise above the level of the canal's water, and that without the admission of any tide-water into the canal, except what happens to get in by the disturbance of the water by the passing of vessels, which, as it will lodge near the upper stuice, the greatest part will be drawn through the hatch of the land-gates of the upper sluice; which ought to be drawn at low water, to let off the water accumulated in the canal and quays by the currency of the river Froome, and to scour the chamber and the lower sluice from the mud lest by the tide.

At neap tides the veffels inward bound come into the chamber as before, as foon as they have water, and wait all together till high water, which being below the level of the canal, the land-gates of the lower fluice are then put to, and the hatches of the land-gates of the upper fluice drawn; by which means the chamber will fill to the level of the canal, and as the land-gates of the upper fluice may then be opened, the veffels may proceed to their births, and those that are ready to go down may hawl in; after which the land-gates of the upper fluice being put to, and the hatches of the land-gates of the lower fluice drawn, the water in the chamber is then reduced to the level of the tide in the river; the gates of the lower fluice may then be opened, and the veffels proceed with the tide.

When water is plentiful in the river Froome, the vessels going up at neap-tides may be penned through the chamber, by drawing the hatches of the upper land-gates some time before high water, which will afford more time for the vessels going down to get into the chamber before the tide is much abated; otherwise it will be most adviseable, that after the vessels going up are gone out to their births, to keep the water against the land-gates of the lower suice till the next tide, when all the vessels going out will have time to get into the chamber, and be ready to go out all together at high water. By this method of passing, the vessels inward bound one tide and outward bound the next, they will all have all the benefit of the full tide, and the whole of the water expended in twenty-four hours will be only so much from the canal as is necessary to fill the chamber from the level of high water to the level of the canal; and I apprehend the

feason is seldom so dry, but that the currency of the Frome will, at an average, replace this to the body of water contained in the new canal and quays in twenty-sour hours; but, by way of further supply, as no water will be wanted from the canal to pass the vessels in spring tides, an accumulation of a foot may be retained without prejudice, which, upon so large a surface as will be contained in the new canal and quays, would alone be nearly equivalent to the water expended in the chamber for passing the vessels, according to the last proposed method. Yet, as a sheet anchor, the pond of Newgate Mill may be had recourse to, upon paying an equivalent; but which, from the reason already stated, I don't apprehend can be wanted above once in seven years.

As by this method the tide-water will be almost wholly excluded, there will not be a need of often scowering; but, when this is done, the hatches proposed at New Bridge will be of use, and the hatches upon Newgate Mill Pond will be still of surther use; but I don't apprehend this operation will be needed above twice, or at most sour times a year.

### OBSERVATIONS.

1st. A power of diverting other streams into the river Froome upon necessary occa-

2dly. The sea-gates of the upper sluice are to have no draw-hatches, which will effectually prevent the ships from penning into the canal with the tide's water.

3dly. By these constructions, whenever there is water to bring up a ship to the tail of the canal, she is always enabled to get to the quay.

4thly. The ships being kept constantly afloat, the river Frome will of itself birth a great number, and the new canal will birth twenty-four ships, besides leaving a sufficient passage; but, by making it wider, will birth a greater number; every ship's breadth in width makes an addition of twelve births.

5thly. The expence, as near as I am at present enabled to calculate the same, will be as follows.

ows.		6555	0	•
To digging,		4887		
Quay walling, -	-	8000	0	0
The two fluides,	,	1000	0	0
The two fluces, The dam and harches across the present mouth of Frome river	_	620	0	0
The hatches at New Bridge and upon recognition	ate	3958	0	0
Contingent expences being supposed,	f	23000	0	0

Exclusive of purchase of lands and damages to Bridewell Mill and Tom's Dick.

Briftel, January 26, 1765-

fealon

Bristol, January 26, 1765.

AT a numerous meeting of the merchants of the city of Bristol, this day held, John Smeaton, Esq; having presented to them a scheme and plan for laying the ships at the quay of Bristol constantly associ, and for enlarging that part of the harbour by a new canal through Cannon's Marsh, it was unanimously voted; that the thanks of the gentlemen present be given to Mr. Smeaton for his plan now offered, and for his diligence and attention in this matter.

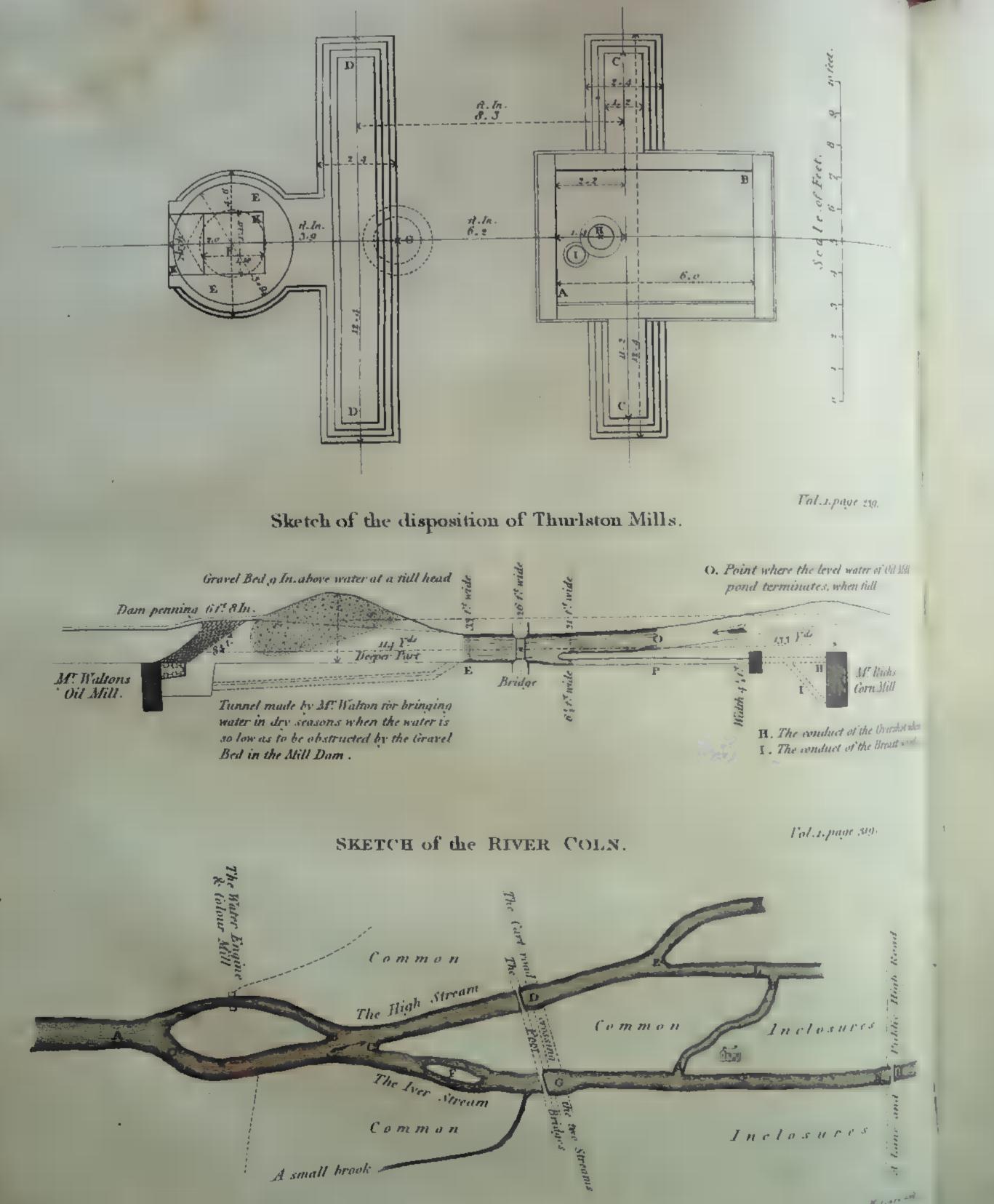
THO. SYMONS, Clerk.

Austhorpe, December 31, 1766.

HAVING perused and considered the plans this day laid before me relative to Bristol Harbour, \* I am of opinion, that the uppermost and lowermost where the sluices are made out of the river, and the dam upon the channel of the river, are more practicable and eligible than the middle scheme, where the whole is done within the bed of the river, and provided the expence of the execution of either of those schemes is no objection, there is no other material one that occurs to me; and respecting the eligibility of the upper or lower scheme, as there is no difference but what relates to convenience and expence, this is a proper subject for the determination of the merchants of Bristol. But whichever of these schemes are executed, I advise, if two passages are made, to keep them entirely separated by a middle wall, and to raise these walls and gates at least 5 seet higher than the crown of the dam, especially at that end next Bristol.

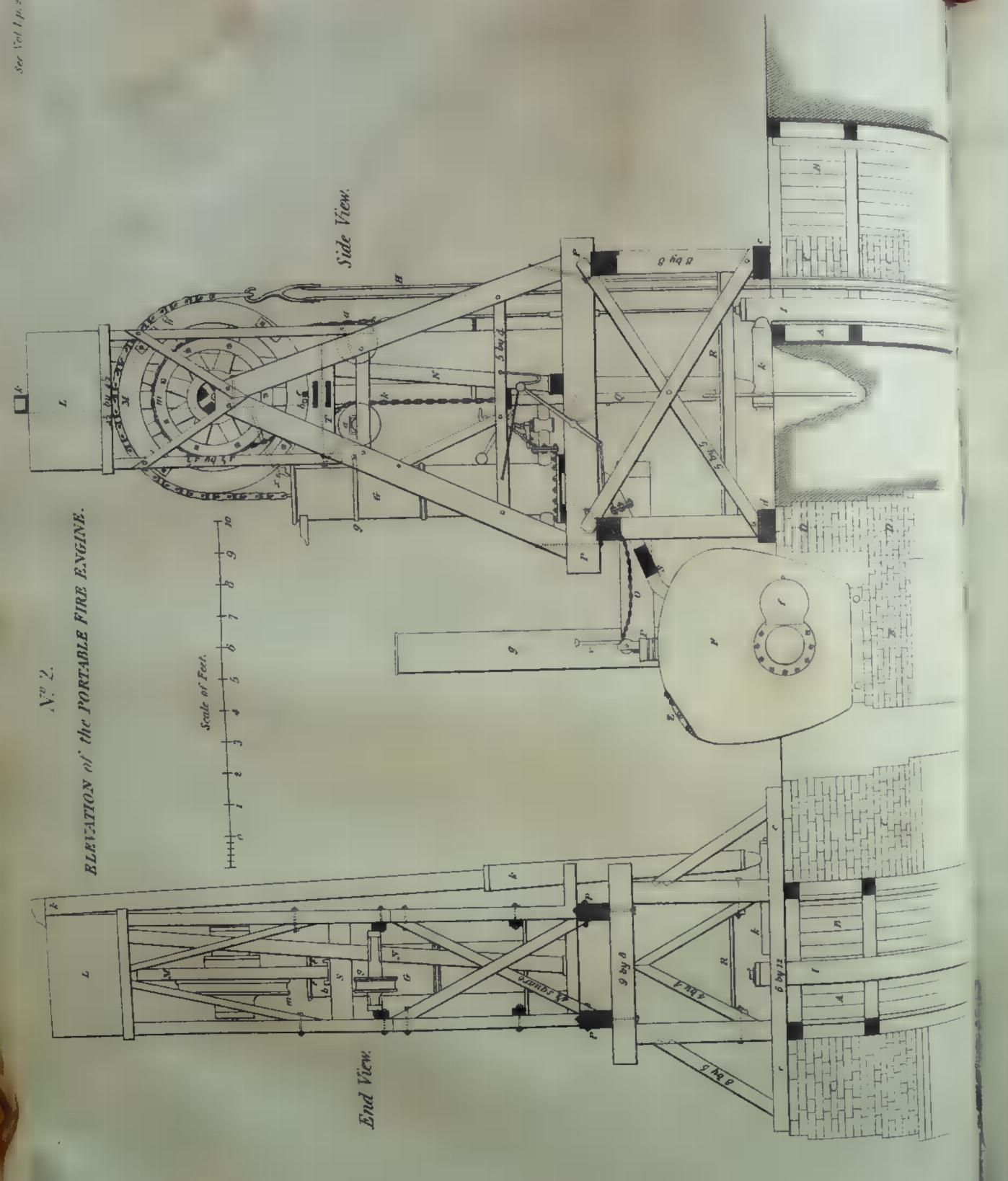
J. SMEATON.

<sup>•</sup> Designs of Mr. Champion, who came with them into Yorkshire in company with Mr. Symons, Clerk of the Company.



"Narcy Jun, del.

Published as the Get directs also, by London in Marst Ress, Print and Brown Patronneter Bon, London.



#### PORTABLE FIRE-ENGINE.

DESCRIPTION of a Portable Fire-Engine, invented by JOHN SMEATON, F.R.S. at the instance of the Right Honourable the Earl of EGMONT, 1765.

No. 1. SHEWS the ground plan of the walls for supporting the engine, which is supposed to be necessary, in order to keep the several parts of the machinery from fettling under the weight, wherein,

A. B. is the pit or shaft.

C. C. foundation walls on each side of the pit, for supporting the fore part of the engine frame across the pit.

D. D. a foundation wall in like manner, for supporting the back part of the frame.

E. E. walling under the boiler.

F. shews the center of the boiler.

G. the place of the cylinder.

H. the main pump.

I. the jack-head pump.

K. K. the ash hole.

No. 2. contains elevations of the engine, viz. an end and side view thereof, when put together, wherein the same letters as are in the plan refer to each.

A. B. is the pit or shaft.

C. C. the upright of the foundation walls on each side of the pit, for supporting the groundfill c. across the pit, upon which one side of the engine frame is raised.

D. D. the foundation wall, for supporting the groundfill d. upon which the other fide is raifed.

E. foundation wall for supporting the boiler, and forming the ash-hole.

F. is the boiler, f. the fire-door, g. the chimney, s. the steam-pipe, p. the puppet. clack, v. the feeding-pipe funnel, z. the man-hole.

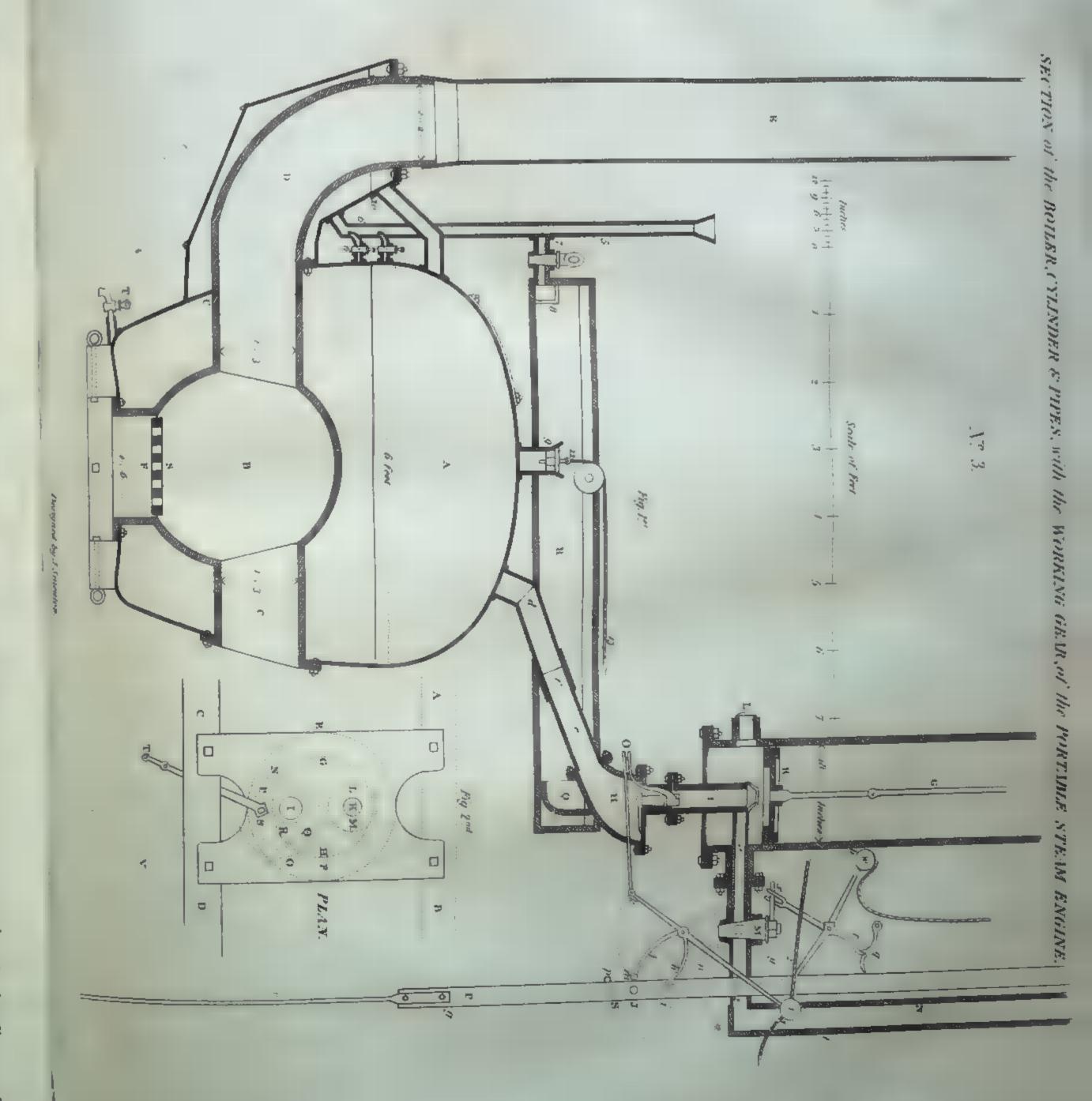
G. the cylinder.

I the jack-head pump, by the continuation whereof k, k, k, the water is conveyed into

L. the injection cistern.

MI.

- M. a wheel serving instead of the great beam, m. rim of a smaller diameter, attached to the former, for working the jack head pump I. and plug-frame of
- a. a. pullies to bring their chains into a convenient place for working. The wheel is stopped at the end of it's intended stroke, which is to be  $6\frac{1}{2}$  seet, stop and stop, by means of the two iron sidds b. b. which, reaching out on each side of the great rim, stop against two strong iron pins s. e. which are sixed into a cross beam S. framed into the piece T. and the whole sirmly bolted together, as shewn in the design; N. is the injection-pipe, n the injection-cock, and x. the piston water-cock.
- O, is the hot well.
- R. a stage for the person to stand upon, who hands the engine.
- P. P. are the two main-beams or fleepers, upon which the cylinder is scated upon it's bottom, and bolted down; the whole is kept from springing or slying off by the iron strap q.
- N. B. The waste water-pipes are omitted to prevent consuston.
- No. 3. Fig. 1. shews a section of the boiler, cylinder, and pipes, with the working-gear, to a larger scale, the whole being divested of the framing, in order to render every thing more distinct.
  - N.B. The boiler is supposed to be turned one quarter round, from it's true position, as in No. 2. in order that the most material parts may be brought into one view. It is also to be noted, that every vessel or pipe is supposed to be cut right through the middle, in order to shew the contents, and not that the section is confined to any particular plane; but, for the more perfect explaining of the principal figure, it will be best to begin with the little plan marked Fig. 2. wherein
- A. B. C. D. is a plan of the cylinder bottom, bolted down upon the two main beams A. B. and C. D.; the dotted circle E. F. shews the extremity of the bottom flanch of the cylinder, and the circle G. H. the diameter of the cylinder within; the hole I. answers the steam-pipe and regulator; and the hole K. the eduction or sinking pipe, and the circle I. I. it's flanch; the circle I. I. she size and position of the regulator plate, and the dotted circle I. I. the size of the receiver, in which the sliding valve of the regulator I. works, and in this position is open; I. Is the lever by which it is worked; and when that is brought forwards into the position I. I. then the valve covers the aperture of the regulator.



#### Explanation of Fig. 1.

A is the boiler, and

B the fire-place, which is intended to be of a spherical figure, of cast iron, and intirely within the boiler; the coals are to be introduced by the large pipe or opening C and the smoak carried off by the curved pipe D; and, in order to promote a sufficient drast, the iron sunnel E. is added. The ashes fall through the grate S and wide pipe F, into the ash-holes below. The whole being joined to the boiler by proper flanches, as is shewn in the figure, and always covered with water, as will be known by the two gage cocks a, b.

Though it is expected that a finall force of fire thus applied will keep the engine going, yet as that force cannot be wholly exhausted within the compass of the boiler, it is proposed to surround the curved pipe D with a copper vessel, somewhat adapted to the shape thereof, as represented in the figure, in which it is proposed to bring the feeding water, which will hereby be prepared to a greater degree of heat than if brought immediately from the hot well into the boiler; into which it is to be introduced by the little hole at c.

The bars of the grate S are intended to be cast in a loose ring, capable of being taken out, and replaced when occasion requires.

T a cock for emptying the boiler when it wants to be cleaned.

G is the cylinder into which the steam ascends from the boiler, by the pipes de HI, of which de are the copper, and are disunited at f, for the sake of taking the engine easily to pieces; and are joined by first bending a piece of lead round the joint, and then wrapping them with cloths and cords, as is common in great engines.

H is the receiver for the steam, of cast iron, containing the regulator valve; and I is the steam pipe, by which the steam passes to the cylinder when the regulator valve is open, which in the present situation of the engine it is supposed to be, in which case the piston K will begin to return.

L is the snifting clack, at which the steam at this instant blows out.

M the injection cock, which is now shut.

N the injection pipe, which brings down the water from the cistern above.

O that part of the injection pipe that conveys the water into the cylinder, when the injection cock is opened, and which terminates in a cap that directs the jet of water perpendicular; the injection cap is in the center of the cylinder, but as part of the termination of the injection pipe lays behind the steam pipe I, it hinders the complete view thereof; the other parts will perhaps be better described by an explanation of the operation of the engine. Operation

#### Operation of the engine.

To render this explanation intelligible, it is to be premised, that the plug-frame P. which moves up and down with the pifton, but with a different velocity, according to the diameters of the two wheels, (M and m No. 2) is furnished with pins, which lav in four different planes, answerable to four different detents or arms of the working gear: the pin 3 lays upon the fore fide; the ping lays in a mortoife, which divides the plug-frame into two parts, the pins S, I, 2, lay upon the far fide, and the peg p stands in the place of the plug-stame, upon the further cheek. Now when the piston is risen as high in the cylinder as it's stroke is intended, the pin g having met the arm b of the tumbler ik, overfets it into the position im; so that the point k moving into the place of m, the regulator valve is shut, by drawing the rod ko, which takes hold of it's lever towards the plug-frame; and at the same instant the peg p rising so as to lift up the catch q, the beak of the faller (or F as it is commonly called) marked r, is disengaged therefrom, and the weight w, by descending into the place v, carries the fork x along with it, and therewith the lever that turns the injection cock into the place y, and whereby that cock is opened, the jet played, and the fleam reduced into water, (or condensed, as it is commonly called) hereby a vacuum being produced within the cylinder, the pressure of the air causes the piston to descend, and in descending, the peg S, on the far side, meeting the faller at t, carries it down to z, which thuts the injection cock, and also hooks the beak behind the catch q, and thereby the tail ! ! becoming parallel to the plug-frame, the pins succeeding the pin S, retain it in the same position, the piston still descending till the peg 3 on the fore side laying hold of the arm 4 of the tumbler at n, thereby brings back the regulator into it's present position, and the further descent of the piston is stopped by letting in the steam.

The water thrown in by the injection at each stroke, and also generated from the steam, is evacuated while the piston is rising, by means of the eduction or sinkingpipe, and valve Q; this pipe laying exactly behind the steam-pipe I, is thereby, in a great measure, hid; the steam-pipe is carried several inches above the bottom of the cylinder, to prevent the injection water from running into the boiler; but the eduction-pipe rises no higher than the bottom, in order to lead the water into it; and as the bottom of the cylinder is commonly elevated from 11 to 3 feet above the valve at the bottom of the eduction-pipe, commonly called the horse-soot valve, the preifure of this column of water opens the valve, and makes it's way into the eiftern  $R_1$ called the hot well; but when the vacuum is made, this valve shuts, and being immersed under the surface of the hot well water, is thereby kept air-tight.

An there is a confiderable quantity of air lodged in water, when in it's natural state, which separates itself by boiling, and, in some degree, by considerably heating, it follows that a quantity of air passes along with the steam into the cylinder, and that I further quantity escapes from the injection water, by being considerably heated with the steam; and though air is capable of being considerably expanded by heat, and contracted by cold, yet the degree is so very much less than that of steam, that if the air generated at each stroke was not evacuated, it would quickly render the vacuum so imperfect, that the piston would stop in the middle of it's descent. Now as the air will be lodged, when the piston is down, between the surface of the injection water laying upon the bottom of the cylinder and the piston, in order to get rid of it, the fnifting clack L has been happily applied; for, on the first rush of the steam into the cylinder, the piston not being instantly put into a contrary motion, the steam, finding a passage at the snifting clack for a small space of time, blows out thereat, and therewith carries the whole or the greatest part of the air generated at each stroke, so as to prevent it's increase beyond a certain degree.

The surface of the hot well water being in general from 3 to 5 feet higher than the surface of the water in the boiler, this height of column is sufficient to force it's way into the boiler, though resisted by the action of the steam within, when sufficiently elastic for use; it therefore finds it's way down the seeding-pipe 5, 6, through the feeding-cock 7, which is opened fo much as is found necessary for supplying water to the boiler as fast as it is consumed in steam. It is evident, that whenever the repellancy of the steam within the boiler is not too great to suffer the surface of the water in the feeding-pipe to be below that of the hot well, that the boiler will feed by the passage of the water into the pipe; but whenever the repellancy of the steam is such as to keep the water in the feeding pipe above that point, that then the water will revert into the hot well; but as the repellancy of the steam within the boiler is alternately greater and less, as the regulator valve is shut or open, during each stroke of the engine, it follows that the boiler may feed while the cylinder is drawing the steam from the boiler, and revert while the piston is descending. In order, therefore, to make this matter fafe, and at the same time to bring the engine into as small a compass as possible, the valve 8 is placed in a little box in the hot well, to prevent such a reverfion. It is necessary to continue the feeding-pipe as usual considerably above the hot well; for as the water is in a vibrating state within this pipe, according to the variable repellancy of the steam within the boiler, this extension is to prevent it's frequently overflowing; for it is necessary to be open at the top, otherwise the steam generated therein would prevent it's feeding at all, or very irregularly. N. B.

Gg2

N.B. The hot well is, in this view of the machinery, represented considerably larger than it is; for supposing the boiler turned a quarter round while the feeding pipe 5 6 falls directly behind the pupper clack 9, as shewn in the general elevation, the hot well will then be shorter by half the diameter of the boiler.

The puppet-clack 9 has no other use than being loaded with a certain weight, in proportion to it's size, that whenever the repellancy of the steam in the boiler is greater than to lift up this clack, it evacuates without bursting the boiler, which it otherwise might do, and, when the engine is stopped, the person attending lifts it up by the cord 12, 13, in order to discharge the steam.

A pipe of communication for steam, 10, 11, between the receptacle for seeding and the boiler, will be necessary; for while the boiler is heating to make the engine work, (after standing some time) the seeding-cock being then shut, the water in this receptacle will boil before that in the boiler, and possibly, by the sudden expansion of the steam upon boiling, might burst this vessel before the water could be evacuated at the little hole c, and yet, if so, being emptied of the water, might, by overheating the copper, break the soldered joints.

N. B. It is to be understood that in this, as in all other engines, the weight of the main pump-spear is so far to exceed the weight of the piston as to raise it, and overhaul all the gear, and that if not so, must be weighted till it will do it.

I have faid nothing of the measures, for as every thing is drawn to the scale annexed, I did not chuse to perplex the account therewith.

## Calculation of the effects of this engine.

The diameter of the cylinder being 18 inches, the area in circular inches will be 324 inches, and allowing 7 lb. to the inch, which such a cylinder will very well carry, we shall have 2268 lbs. equal to the weight of the column of water to be listed = 1 ton and 1 quarter of an hundred weight.

The pump working barrel being supposed of 7 inches diameter, the weight of a column of water that size, and 1 soot high, is 16.7 lbs. by which dividing 2268 lbs. to be raised, we have 135.9 seet for the height of the column  $= 22\frac{2}{3}$  sathoms nearly, by a similar process, if the working barrel is 8 inches, the height of the column raised, will be  $17\frac{1}{3}$  sathoms, and if of 9 inches,  $13\frac{2}{3}$  sathoms.

Such an engine may be expected to make ten strokes per minute, of 6 feet each, effectively; this, with the 7 inch bore, will produce  $98\frac{1}{4}$  ale gallons per minute, that is 113 hogsheads wine measure per hour; the 8 inch bore will produce  $128\frac{1}{4}$  ale gallons per minute, that is, 148 hogsheads per hour; and the 9 inch bore will produce  $162\frac{1}{2}$  gallons per minute, or 187 hogsheads per hour.

It has been found by experience, that a 2 feet cylinder can be worked by one bushel of Newcastle coals per hour; the present cylinder being but 18 inches, the capacities will be as 16 to 9; therefore if a 2 feet cylinder takes 24 bushels per day, an 18 inches cylinder will take but  $13\frac{1}{2}$  bushels per day, according to the common application of fire; but I have reason to think an engine constructed like this will not require above 9.

It has also been found by experience, that a horse will raise about 250 hogsheads 10 feet high per hour; consequently only 30½ hogsheads at 13½ fathom = 82 feet; but 187 hogsheads raised to that height by the engine, is more than fix times the quantity raised by one horse, and consequently acts with more than the power of six horses at a time; but in order to keep up this force with horses, night and day, three sets will be required, and consequently this engine will be more than equivalent to eighteen horses.

### WHITBY HARBOUR.

2 orkshire, to wit, At the affizes held at the castle of York, in and for the said county, on Saturday the 20th day of July, in the sisth year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of Great Britain, &c. and in the year of our Lord 1765, before the Honourable Sir Henry Gould, Knight, one of the Justices of his Majesty's Court of Common Pleas, and the Honourable Sir Joseph Yates, one of the Justices of our Lord the King, assigned to take the said assizes according to the statute.

## CHOLMLEY, Esq; against Howlett and Mathews.

TT is ordered by the consent of the said parties, and their attornies, that the last juror or jury empannelled and sworn in this cause be withdrawn from the said pannel, and by the like consent it is ordered that the plaintiff shall execute, and the defendants shall accept, a lease with proper covenants for repairs by the defendant, and all other usual covenants, of the plaintiff's mills and fishery, in the pleading of this cause, mentioned at a rent equal to the highest neat profits, to be computed on a mean of any three successive years to be named by the plaintiff, which shall appear to the satisfaction of FOUNTAIN WENT-WORTH OSBALDESTON, of Hunmanby, SIMON BUTTERICK, of Thirsk, and JOHN GRIMSTON, of Kilnwick, Efgrs. or any two of them, to have been made at the premiles by the plaintiff; and also to enter into such covenants for cleansing the harbour of Whithy from the allum shail, which hath come from the defendant's works, within such time and in fuch manner as JOHN SMEATON, Esq; and JOHN WOOLER shall think reasonable, and also for the security of the said harbour from suture damage from the defendant's allum works. The furvey and award of the faid John Smeaton, Eigi and JOHN WOOLER to be made on or before the 7th day of November next, and at the joint expence of the faid parties; and it is further ordered that fuch security shall be given, and penalties provided for the performance of the aforesaid covenants, as the said FOUNTAIN WENTWORTH OSEALDESTON, SIMON BUTTERICK, and JOHN GRIM-אסס, or two of them, shall think reasonable and susticient, and that the lease to be made shall be executed on or before the 20th day of December next, and shall commence, together with the rent, at that time, for the term of 99 years.

And it is also ordered that there shall be no costs on either side, and that the defendants shall consent that the plaintiff's bill, now depending in the Court of Chancery, shall be difmissed

missed without costs; and that all other proceedings or actions now depending between the said parties, either at law or in equity, touching the matter in question in this cause, shall cease, and that no writ of error shall be brought, and that no bill in equity shall be filed against the said Fountain Wentworth Osbaldeston, Simon Butterick, John Grimston, John Smeaton, and John Wooler, or any of them, for any thing done by them under or by virtue of this order; and that this order shall be made an order of his Majesty's High Court of Chancery, if the Lord High Chancellor shall so please.

By the Court.

To all to whom these presents shall come, JOHN SMEATON, of Austhorpe, in the county of York, Esq; and JOHN WOOLER, of Whithy, in the said county, Gent. send greeting. Whereas, by rule of court, made at the affizes held at the castle of York in and for the county of York on Saturday the 20th day of July, in the 5th year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of Great Britain, and so forth, and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of His Majesty's Court of Common Pleas, and the Honourable Sir Joseph YATES, Knight, one of the Justices of our Lord the King, assigned to hold pleas before the King himself, Justices of our said Lord the King, affigned to take the faid affizes according to the statute, &c. in a cause then and there depending between NATHANIEL CHOLMLEY, Efq; plaintiff, and SAMUEL HOWLETT and JOHN MATHEWS, Gents. defendants, it was ordered, by the confent of the said parties and their attornies, that the last juror of the jury impannelled in the faid cause should be withdrawn from the said pannel, and by the like consent it was ordered (among other things) that the faid defendants should enter into such covenants for cleanling the harbour of Whithy from the allum shail, which had come from the defendants works, within such time and in such manner as we the said JOHN SMEATON and JOHN WOOLER should think reasonable, and also for the security of the said harbour from future damage from the defendants allum works. The furvey and award of us the faid JOHN SMEATON and JOHN WOOLER to be made on or before the 7th of November then next, as by the faid rule of court, reference thereunto being had, may amongst other things fully appear. Now know ye, that we the said John Smeaton and JOHN WOOLER having viewed, surveyed, and examined the said harbour of Whithy and the river Ejke as far upwards as Ihrondale Beck, and the faid Beck as far as the allum works of the faid defendants, which are fituate and lying contiguous to or near the faid Beck, and also the said allum works, we find that not only the harbour of Whithy above the bridge there, but the channel of the river Eske as far upwards as the said Ibron-

dale Beck, is greatly obstructed with allum shail, and also that the channel of the said Ibrondale Beck is greatly obstructed, and in some places nearly filled up, by the allum shail therein; and that the allum shail being in the said harbour, river, and beck as aforesaid, has all proceeded from the said allum works of the defendants, and has been carried down into the faid river and harbour, in the time of floods and freshes, from the faid beck; and that the said harbour of Whithy above the bridge there is greatly damaged thereby; and we also find that the manner in which the said allum work is carried on is fuch as will occasion still greater damage to the faid harbour than it has yet received, by reason of other great heaps of shail and rubbish, from time to time proceeding from the faid works, must necessarily fall into the said beck, and by the waters passing through the same in time of sloods and freshes be washed and carried down into the said river, and from thence, by the faid waters, and the additional waters coming down the faid river above the faid beck, carried into the faid harbour, and there scattered about in an irregular manner, to the great detriment thereof, and particularly by filling up and cheaking the channel of the faid river, where ships of great burthen lay or have usually laid between the bridge of Whithy and about 160 yards above a place called the Oil House, and which was formerly called the Stone Key.

We do therefore order, adjudge, determine, and award, that the faid defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually cleanse the present channel of the said river Eske, running through that part of the said harbour of Whithy laying above the bridge therefrom, and remove and carry away all the allum shail that shall be found at the time or times of such cleansing laying in the said river or harbour, between the said bridge of Whithy to 160 yards above the south east corner of the building or warehouse now commonly called the Oil House, and which was formerly called the Stone Key, and which shall be sound above the surface of a plane regularly inclined so as to be 14 feet below the top of the uppermost aister course of stone in the present south east angle of the said Oil House as it now is, and 16 feet below the top of the uppermost aister course of stone under the threshold of the door on the east side of the warehouse or storehouse belonging to Mr. Plummer, being situate contiguous or near to the west end of the said bridge; and also that they shall take and carry away all such allum shail as at the time or times aforesaid shall be found laying on the sloping sides of the said channel.

And we do further order, determine, and award, that the faid defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually make, do, and perform, or cause to be effectually made, done, and performed, all such cleansing of the said river and harbour as herein before ordered and awarded, on or before the 29th of September, which shall be in the year of our Lord 1766.

And

And we do further order, determine, and award, that the faid defendants and their or one of their heirs, executors, administrators, or assigns, shall from to time, after the faid 29th of September, 1766, take away and remove, or cause to be taken away and removed, all such allum shail as shall be found above the level of the plane above specified, or laying upon the sloping fides of the said channel; which allum shail we adjudge must happen to be so found or laying so long as the said allum works of the said defendants shall be carried on in the manner they are at present, and so long afterwards as any of the shail proceeding therefrom, and laying in the said beck and river above the harbour of Whithy, shall remain therein in a state capable of being removed by floods. And we do also further order, determine, and award, that all such allum shail as shall, on cleansing the said harbour aforesaid, be taken away, shall be by, or by the order, and at the cost and charges of the said defendants, their or some of their heirs, executors, administrators, or assigns, carried or removed and lodged above the high water mark of spring tides, and deposited and laid in such a manner as no part thereof may at any future period of time slide or fall down into the said harbour, or otherwise that it shall be carried directly to sea, and discharged there in not less than 14 fathom of water. And lastly, we do order, adjudge, determine, and award, that the said defendants shall, within 40 days after the date of this our award, enter into and make, and duly execute, a deed of covenants between them and the faid NATHANIEL CHOLM-LEY, or his heirs, wherein and whereby the defendants shall, for themselves and each of them, and their and each of their heirs, executors, administrators, and affigns, and every of them, jointly and feverally covenant, promite, and agree to and with the faid NATHANIEL CHOLMLEY, and his heirs and assigns, that they the said defendants, or their or one of their heirs, executors, administrators, or assigns, or some of them, shall and will from time to time, and at all times hereafter, at their own cost and charges, well and truly make, do, perform, and execute, or cause to be well and truly made, done, performed, and executed, all and every the act and acts, thing and things whatfoever, before by us ordered, directed, determined, and awarded to be by them, or any of them, made, done, executed, and performed, or cause to be made, done, executed, and performed as fully and effectually, and at or within fuch time or times, and in fuch manner as herein before mentioned, and according to the true intent and meaning of this our award. In witnels whereof we have hereunto set our hands and seals this 18th day of October, in the year of our Lord 1765.

Signed, sealed, published, and declared by the above-named JOHN SMEATON, as his final award and determination, in the presence of us.

Vol. I.

Signed, fealed, published, and declared by the above named John Wooler, as his final award and determination, in the presence of us.

Hh

MARKET

# MARKET WEIGHTON.

HAVING viewed the out-fall cloughs of Fursdyke and Hudlett, as well as the leading drains up to Hotham Carrs, and from thence the country between this and Market Weighton, it appears to me as follows:

- 1st. That the most slooded part of those levels is Hotham Carrs, and parts adjacent to Wholsea.
- 2d. That the general surface of the lands in those Carrs lay at least 7 or 8 seet above the floor of Hudlett Clough; and therefore,
- 3d. That by sussicient drains the surface of the water might be reduced 5 or 6 seet in Hotham Carrs, opposite Wholjea, even as Fursdale and Hudlett Cloughs now stand; and therefore
- 4th. That all the drainages which come to Hotham Carrs, by way of Foulney or Black Dyke, &c. may be equally reduced and improved; and consequently,
- 5th. That all the adjacent country may by proper branch drains be refitted in like manner, by running their waters proportionably lower than they can by the present drains.
- 6th. It appears that Hudlett Clough (which I look upon to be lower than that and Furf-dyke) lays at least 3 feet above low water mark spring tides; and therefore,
- 7th. That by erecting a new clough of proper dimensions, the waters might be run off at least 3 feet lower than they can possibly be done by the present cloughs, though the drains leading thereto were perfect.
- 8th. That from Hotham Carrs the low grounds have a confiderable rife towards Market Weighton; and confequently, that
- 9th. The affair, so sar as regards to the drainage of these levels, will be perfectly easy and well conditioned, and executed at a very moderate expence, in proportion to the extent and value of the lands to be benefited thereby.

roth. Respecting navigation, it is no ways incompatible with drainage; for provided the cuts are made at an average from 18 inches to 1 feet deeper, the drainage will remain equally good, as if no navigation.

11th. A navigation may be made any where by means of locks, where there is water to supply them.

12th. Several locks will be required between the Humber and Market Weighton, besides the sea-lock; I apprehend at least 4.

13th. I am of opinion, that the brooks formed from the springs of Sancton and Houghton, which form Beal's Beck, the springs at Godmanham, which form Weighton's Beck, and those of Londebrough, sorming Shipton Beck, when united, as they may easily be near Weighton, are amply sufficient for supplying the navigation-locks thither in the driest season, and I am inclined to think the two former becks will be sufficient, exclusive of the latter; but of this I cannot be certain, unless I saw the currents of those becks in the driest seasons.

14th. I apprehend it will be equally evident from the same principles that a navigation is practicable through the levels towards Pocklington, as I am informed the supply of water that way is at least equal if not better; but as I suppose Pocklington lays in an higher situation than Weighton, a greater number of locks will be needful on that account.

15th. It is not possible to ascertain any thing respecting the cost of drainage or navigation towards either the towns of Weighton or Pocklington, without an actual survey of the principal drains, with a sketch of the adjacent country, as also an accurate level taken from the low water mark at the Humber, distinguishing the heights of the relative taken from the low water mark at the Humber, distinguishing the heights of the relative furfaces of the water and lands up to the respective points where the navigation or drainage is supposed to terminate.

Hh2

November 29, 1765.

J. SMEATON.

Description of a new Bucket for Fire Engines.

N. B. The same things are marked with the same letters, both in the plans and section.

Fig. 1st. A A is a ring of brass about  $\frac{1}{4}$  of an inch thick, to be turned upon the edge so as to fit the working barrel as near as possible, but not to stick in any part; but it will not be a fault if not more than  $\frac{1}{16}$  of an inch less than the barrel; this being prepared, all the rest is made from it.

Fig. 2d. BB is a ring of forged iron, about 1 inch thick, and turned or filed round upon the edge, so as to be about  $\frac{1}{8}$  of an inch less in diameter than the brass ring; this ring must be pierced with 4 oblong holes or mortices CCCC, of inch long and  $\frac{1}{4}$  inch wide, and 8 round holes a a, &c. which are to be tapped so as to take an  $\frac{1}{2}$  inch screw. This ring is also surnished with a bridge or bar DD, which may either be made of one piece with the ring, as represented at the end d, or let in with a dovetail, and rivetted, as represented at the end e, either way, as the similar can best do it, so as to make all level on the upper side. The bridge is also surnished with 3 round holes of the same size, and tapped as the sormer.

Fig. 3d and 4th. By means of the 4 square holes, the iron ring is to be sastened to the end of the spear rod, whose bottom part is to be divided into 4 branches, two of which, E.E., are shewn in the upright section, sig. 4, and the horizontal sections thereof, sig. 3, supposed to be cut off a little above the ring, are marked with the same letters; the dotted lines distinguish the mortices, as in sig. 2d, and what lays without shews the shoulders, against which the upper side of the ring is brought square, and rivetted on the under side, by means of the tapt holes in the iron ring, and the plain holes in the brass ring, which are to be made answerable to each other; the 2 rings are to be screwed together by 8 screws, such as represented ff, &c. and betwixt the rings is to be screwed the leather g g g, &c. turned up round the iron ring like a dish, the skin or hair side being next the iron ring, and the opposite or sless fide next the barrel, the middle part of the leather being cut out answerable to the inside of the rings.

HH are the valves which are to be screwed down upon the bridge by 3 crews iii, which confine down the rider KK, which is to be somewhat sloped and rounded to-

Fig. 2. Pig. Section 15 of the WHOLE, put together. Plan ( iti) the of RING.IRON (1) Fig. L. Plan the WHOLE, Plan of of the together. BRASS RING. put Smanned by Allenn I

Landon Published by Longman there, Rees & Come, Min

DESIGN for a NEW BUCKET for FIRE ENGINES.

ward the under side, to give more room for the leather of the valves to bend in the joints. I I are the upper plates upon the valves, and mm the under, which ought to be thin, to prevent stopping the water.

N. B. Small screw bolts with thin flat heads laying underneath, will be preferable to rivets for the valves, as the leather may be more easily shifted.

L, the shank, where the 4 arms are joined into one, by which it must be united to the take-off joint.

## OBSERVATIONS to be regarded in making the above.

1st. The brass ring had best be cast without holes, that when the holes in the iron ring are tapped, the brass may be marked off from it, drilled, and opened answerable to the iron.

2d. The iron ring had better not be edged till the two rings are screwed together, by which means the border may be reduced to a breadth all round.

3d. The square mortices must be chamsered or opened on the under side, in order to receive a firm rivet when filed slat, and particularly end-ways; for this purpose the mortice should be at least  $\frac{3}{6}$  longer and  $\frac{3}{16}$  wider below than above, and the slope to reach  $\frac{3}{6}$  upwards at the ends, and about  $\frac{5}{16}$  at the sides.

4th. Particular care should be taken, that the tenons of those mortices at the end of the branches should be sound and tough iron, but not the softest, and that they may be rivetted with a hammer as heavy as a common hand hammer, that the metal may spread as well within as without.

5th. The tenons of the branches, I believe, had best be formed angle-wise upon 4 square bars, for then they will be in right position, when laid star together, in order to be welded into one.

6th. The leather dish is to be formed as follows. Prepare an iron hoop about 1½ inch broad, as near as possible the size within of the barrel, but better lesser than bigger; inch broad, as near as possible the size of the iron ring, Fig. 2d. but rather bigger prepare also a round plug of wood the size of the iron ring, Fig. 2d. but rather bigger than less; let the plug be turned truly round, of some close wood, and square at the end; let your leather be of the best bend, but not the thickest; those are best that are evenest of a thickness; cut out a circle of leather 2½ inches more in diameter than are evenest of a thickness; cut out a circle of leather 2½ inches. When the leather is well the pump barrel, therefore for a nine-inch barrel 11½ inches.

foaked in water, lay it upon the ring, with the hair side uppermost, set the plug upon it, and with a few blows of a beetle, the leather will be forced into the ring, and will turn up round the sides in the same manner it is to lay in the pump, and thereby form a border without a joint of about 11 inch broad. When it has stood while take it out, and put it upon the iron ring of the bucket, and with a round-faced hammer beat the leather a little down upon the ring opposite to the holes, by which means their places will be marked; cut them out with any proper sharp tool, but the best is a leather punch, which is made for the coachmakers, big enough for this purpose. This done, serew it into its place, trim it to an equal breadth, and chamfer the edge towards the barrel. as represented in the section, and cut out the middle answerable to the rings. In this way feveral leathers may be prepared at once, provided those that are to be kept are put on round boards, or something to keep them from drying into a lesser diameter. As the wet dries out, keep supplying them with oil, either train cil or sweet oil, or any oil that is not of a drying nature, till the pores of the outward rim of the leather that works against the barrel be in a good measure saturated therewith, and let this be done for the first leather as well as the rest; when the bucket is lowered down into its place, it would be well to pour down about tof a pint of oil round the fides of the barrel, by which means, when the engine makes a stroke, the inside of the barrel will become besmeared therewith; but oil in the bending joints of the valves is rather to be avoided.

N. B. If on cutting out the circle of leather from the hide it appears thicker on one fide than the other, let it be shaved with a sharp knife, so as to be of an even thickness.

If a barrel is very smooth bored without ring-galls, I esteem the surface best that is lest by the tool; but if otherwise, let it be rubbed with a fine grit-stone; none better than the grindstone kind that is got on Gatesbead Fell. After the barrel is bored or cleansed as above, let its inside surface be oiled over, which will prevent its immediate rusting; and if so preserved till used, will make a great difference in the first leather.

The tenons at the end of the branches, by which the whole column is to be suspended, will undoubtedly seem small and weak; but it is to be remembered, that the bucket I saw at Aller Dean hung by two parts of basely figure each, that is 50 square eighths; whereas 4 Parts of 1 inch by fare equal to 64 square eighths. After all, a column of 27 sathom and 9 inches diameter weighs but 2 tons, so that each part has only 10 cwt. so carry; therefore there is no doubt of their sufficiency, if good iron and well put together.

N. B. There is no objection to lengthening the mortices,

# THURLSTON MILLS.

The REPORT of JOHN SMEATON, Engineer, touching the matter in dispute between Mr. RICH and Mess. WALTONS, concerning their mills at Thursson.

A S no particular question has been formally stated to me in writing, I apprehend the matter in dispute to be reducible to the following, viz.

Whether Mess. Waltons have done any thing, by the erection of their oil mill dam, which they have no right to do, and whereby Mr. Rich's corn mill may at certain times be affected, and stopped by back water?

As it will fave many words, I refer to maketch of the river and premises in question, hereunto annexed.

The rule that I have constantly sollowed myself in regard to the placing intermediate dams, whether for the erection of mills or navigations, and the same rule I have found practised by the best engineers and millwrights, and which is found generally substituting in ancient mills. In stat countries, where levels are scarce, and consequently stail or back water most burthensome and annoying, is to build those dams so, that each dam shall not pen into the wheel of the mill next above, when the water is in it's ordinary summer's state.

This rule I apprehend to be founded upon the following reasons: that if the erection of m dam does not affect the mill above by tail-water, when water is the most scarce in dry seasons, as every mill that is well and properly constructed will clear itself of a in dry seasons, as every mill that is well and properly constructed will clear itself of a in dry seasons depth of tail-water when it has an increase of head and an unlimited considerable depth of tail-water when it has an increase of head and floods, at the same quantity of water to draw upon the wheel; and as in freshes and sloods, at the same time that they bring a quantity of tail-water upon the wheel, they also increase the head, and afford a superior quantity to be expended. This is looked upon to be the head, and afford a superior quantity to be expended. This is looked upon to be the proper means, and equivalent, by which mills are to be cleared of back-water, as far proper means, and equivalent, by which mills are to be cleared of back-water, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the mutual enjoyment of those great benefits of nature, namely, as is consistent with the end of the end of

mills well constructed will bear 3 and even 4 feet and upwards of tail water; I have feen an instance of 6 feet; and it is a common thing in level countries, where (as faid before) tail water is most annoying, to lay the wheels from 6 to 12 inches below the water's level of the pond below, in order to increase the fall of water, and, if judiciously applied, is attended with good effect.

If the rules above laid down are not decifive betwixt man and man, I believe it will be difficult otherwife to draw the line; for while fome may think 3 inches a fusficient clearance, others may think 3 feet too little; and a third may subject himself to an action at law, after having been at a great expence and upon the best advice, for having done something to interrupt the free passage of the water 30 feet perpendicular below another's works, for there is no limits to fix the extent of imaginary evils.

I suppose it is a rule in the law, that no man can possess his own property in any new manner, that may be detrimental to his neighbour; but then I suppose it is equally a rule, that no man can acquire an exclusive power over another's property, to prevent him from turning it to profit, in the same manner as the first had done before him. It would feem very strange and unreasonable, and also very detrimental to the publick service, (of which the benefit of mills and machines worked by water is so great as scarcely to be estimated) I say it would seem very strange, if I have an estate through which a river flows, to which no one has any controul but myself, in which there is 10 feet fall, and I have an occasion for a mill as well as my neighbour, that I cannot pen up the water to the same height as it before entered my grounds, and let it go at the same level as it used to depart, because the miller above says, that by keeping up this body of water within my ground, the water does not get away from his mill so freely in time of floods and freshes as it used to do; and the miller below says, Sir, you shall not build a mill there, because I cannot have the water from the mill above I used to do, but will be intercepted by your dam. To the former I should answer, the water shall have the same passage into my estate as it always had, but I absolutely deny that you have ever had any right or occupation of a fall within my land; it is true, I have not made use of it myself before, but as I always had it in my power to do so, as you have done before me, if my not doing it so long has been an advantage to you, you ought to thank me for having it so long, and not to think of precluding me from making the same advantage of the fall within my land, as you have done in yours.

To the miller below I should answer, you shall have the water delivered to you at the same level as before, and in the same quantity, for I neither intend to bottle it up, nor

divert it from you; but as I have the prior right of using the water passing my premises, this I shall do in the same manner as you will do after me.

Thus much by way of explanation of those principles and maxims that it my opinion either are, or ought to be, the medium by which disputes of this kind ought to be adjusted. If they are true and valid, as they appear to me to be, there is not the least foundation for a complaint from Mr. Rich on account of Mess. Walton's oil-mill dam; for it appears to be below the floor of Mr. Rich's mill-race no less than I foot 4 inches, and 10 inches below the bottom of the wheel, in the whole 2 feet 2 inches fall in the compass of less than 100 yards from the wheel complained of to be put in backwater by the said dam: on the contrary, had Mr. Walton penned considerably higher than he has done, he would not, in my opinion, have infringed upon the true rules of mill-building, especially in such a country as this, where the river runs so rapid as seldom to lay any mill in back-water above three hours together, and scarcely ever above six, not even the wheel complained of.

It is observable, that Mr. Walton's dam pens dead water a considerable way up Mr. Rich's goit towards the letter P; but as this goit is without any floor laid, it may happen that a flood coming and washing in gravel, &c. may raise the goit's bottom, while it is above Mr. Walton's dam's water; or Mr. Rich, by clearing the goit, may at pleasure sink it below; or the continual wearing of the mill's water may sink it below; as therefore the bottom of an unfloored goit is of an uncertain level, nothing conclusive can be deduced therefrom: thus much however it is certain, that no part of the oil-mill's dam's water reaches any part of Mr. Rich's goit where any floor or setting is.

How far exactly Mr. Rich's premises extend down the river, I know not; but according to the rules already laid down, if Mr. Walton has penned the water so as to raise its surface against Mr. Rich's freehold, he has done what in my opinion he cannot vindicate; it is however very manifest, that a considerable length of the tail of the jetty has at some time or other been taken off the river, as appears by the river's contracted breadth opposite thereto; and if, by consent of the Lord of the Manor, he has obtained a right of making this sence for the more effectually keeping open his water-course, he has not thereby deprived the Lord of the Manor of the use of such part of the perpendicular fall of water, as Mr. Rich has not by prescription or otherwise obtained the use of; for the sufferance of the Lord of the Manor, in letting a part of the natural that of the river lay vacant, next below Mr. Rich's premises, must be considered in the same light as every other part of the unoccupied sall below.

I shall now proceed to a determination of this simple question, whether Mest WAL-TON's oil-mill dam does or does not affect Mr. RICH's mill by back water, in any degree whatsoever, as they now both stand? In order to this it must be remembered, that the bottom of Mr. Rich's mill wheel lays 2 feet 2 inches above Mr. Walton's dam water, that is, higher by 2 feet 2 inches than the water under the bridge when the oil mill. pond is full: the water therefore under the bridge must be rifen 2 feet 2 inches before it comes upon a level with the bottom of Mr. Rich's mill wheel; and I look upon it as a certainty that Mr. RICH's mill would be going when the water was 18 inches higher than that, provided there were no impediments betwixt the bridge and mill, and the wheel itself properly constructed. Suppose then the water risen to that height under the bridge, that is, 3 feet 8 inches above the dam's height, in which case its mean depth under the bridge will be about 4 feet 8 inches upon 26 feet wide. Suppose now Mr. WALTON's dam away, and the water tumbling from the rock at E, in the manner it is faid formerly to have done, still not above a certain quantity can be vented through the bridge at that given height, no more than can be vented over a dam at a given thickness, though unimpeded by any thing. According to my computation, the quantity that would be vented over the rock and through the bridge at 4 feet 8 inches deep, (supposing the dam away) would be vented over the dam, which is 84 feet in length upon the crown, at a depth of 2 feet 11 inch, or thereabouts. Hence it appears, that in this state of the river there will be a fall from the bridge into the mill-pond of 181 inches, at which difference the bridge and rocks will vent the same water as if the dam was away. This may appear somewhat paradoxical, to those unacquainted with these matters; but it is well known that a stream of water issuing from a sluice, or opening, will run the same quantity so long as it clears its tail, as if unaffected by tail water. At this height the balance is struck, and if at this height Mr. Rich's mill is not going, it must be owing to some impediments between the bridge and the mill, or to something wrong in the construction of the mill itself; at all greater heights the effect of the dam upon the water above is less, at all lesser heights it is greater; but if Mr. RICH's mill ought to go at the height above mentioned, it ought to go at all lesser heights, and if it will not go at lesser heights, it is very plain there is some obstruction between the mill and the bridge.

That there are in fact some obstructions, appear manifest from what JONATHAN LOCKwood the millwright alledged, that is, that Mr. Rich's mill was in back water before the gravel bed in the oil-mill dam was covered; if so, since no part of the gravel bed was above 9 or at most 10 inches above the dam's water when full, it will appear that Mr. Rich's mill is in back water, when the surface of the water in the oil-mill dam (below the rocks) is 1 foot 4 inches below the bottom of Mr. Rich's mill wheel: hence it appears, that very great obstructions are interposed betwixt the rocks and Mr.

RICH'S

RICH's mill wheel. Nor indeed does it need the evidence of Mr. Lockwoon to confirm this, the evidence arising from the things themselves being to me more strong, than that of any man living; for as foon as I fet eyes upon Mr. Rich's mill tail goit, which is some distance below the covered part, not above 41 feet wide, and seems still less where covered; when I observed that both wheels delivered into the same goit, and the breast wheel in a very bad angle, as represented in the sketch, so that the breast mill stream must greatly obstruct the other; add to this, that instead of two small wheels of about 20 inches wide each, Mr. Rich has built one wheel of 5 feet wide, said to be able to drive three pair of stones at once, it is evident that the superior quantity of water necesfary for this purpose, and the additional quantity necessary to be laid on after the tail water begins to touch the wheel; this again, added to the additional quantity also neceffary on the same account to be drawn on the breast wheel, and this all crammed to gether into the same narrow goit that subsisted before the improvement; I say all this considered, it is very evident, that Mr. Rich's mill must be choaked with water for want of sufficient vent. But this is not all; for as the jetty or sence that divides the tail of the goit from the river, as it narrows the river from about 30 feet, which is about the general width, to 21 feet, this will cause the water to swell at least a foot in the contracted part of the river alongside the jetty, when the river is 3 feet 8 inches at the bridge above dam's height; and as the jetty itself, for about 60 feet above the tail, is not at a medium much more than 3 feet above the dam's water, it follows that before the water will rife to the height aforefaid, it will flow freely over the jetty for almost 100 feet upwards into the goit, and thereby fill the goit to nearly the same height as the water in the river abreast of the jetty, which, added to the obstructions before mentioned, must necessarily lay fast the over-shot wheel, long before the water rises to the height under the bridge above specified, according to Jonathan Lockwood's observation.

From what is above laid down it appears, that when the water rifes 3 feet 8 inches perpendicular at the bridge above the dam, that then the dam has no obstruction, because the dam will then vent the water as fast as it could have been vented through the the bridge and over the rocks if no dam was there: but this supposes a free passage for the water between the rocks and the dam. How far the gravel bed at this height of the river acts as an obstruction, (the water being at that time not less than 79 feet wide across the gravel bed) is not easy to say, without seeing the river in that state, the obstruction arifing from the gravel bed not being subject to computation on account of the irregularity of its figure: however, as it must add something, especially at lesser heights, I would advise Mess. Waltons, for the sake of peace and good neighbourhood, (provided Mr. Richt will be contented therewith) to oblige themselves, on or before Michaelmas Day annually, so long as their dam shall remain where it now is, to remove all such gravel as shall be found

in their mill-pond below the rocks, and within the straight line from the fouth end of their dam, to the fouth side of the river where the rocks are, as shewn in the sketch  $r_s$ , and to clear the same so that every part may be at least 8 inches below the top of their dam boards, and to lay the matter thence taken in such manner as not to be subject to get in the same place again. On the other hand, as it does not appear to me that Mess. WALTONS have done any thing but what they may justify; and further, that on the strictest examination it does not appear that Mr. RICH's mills receive any prejudice from Mest. Waltons' works, but that the impediments found therein arise from the miscon. struction of Mr. Rich's own works, I advise Mr. Rich, (if Mess. Waltons will comply in removing the gravel bed as already specified) for the sake of peace and good neighbourhood, to be contented therewith, and drop all further profecutions.

J. SMEATON.

Austhorpe, December 14, 1765.

#### HUBBERT'S MILL STREAM.

The REPORT of JOHN SMEATON, Engineer, concerning the power of HUBBERT's Mill Stream to raise water.

HAVING examined the capacities of the water-way at Hubbert's mill, situated upon a branch of the river Coln, near Drayton, in the county of Middlesex, I found them as follows, upon the 23d of February, 1766: at which time the currency of this branch of the river was faid to be nearly the same as it always is when the mills above, upon the same branch, are at work, or their waste gates drawn, by which means the quantity of water going down this stream is regulated.

			Cube	Feet per Min.
At Hubbert's Mill the discharge by a waste gate within the mill was		-	-	2166
By the water falling over the top of the waste gates without the mill		-	•	396
Total discharge in cube seet per minute -	•	-		2562
				Feet Inches.
The whole fall or difference at the mill was at this time		•	-	5 7

By the help of an hydraulick engine, properly constructed upon that head, and with the quantity of water above specified, the quantity of 356 feet cube thereof may be raised per minute to a perpendicular height of 20 feet above the level of the mill pond, which quantity amounts to 2517 hogsheads per hour, accounting 52 ale gallons to the hogfhead.

N. B. If the height is greater or less than 20 feet, the quantity will be inversely as the height.

It further appears on inspection, that the tail-water of Hubbert's mill (which stands upon a bye stream of the river Coln, as already mentioned) is nearly upon a level with the head water of Lord UXBRIDGE's mill below, which stands upon the main river; and that the tail-water of Hubbert's mill being conveyed by a meandering course, a full mile in length, falls into the main river below Lord Ux BRIDGE's mill: hence it is to be inferred, that in the tail-stream of HUBBERT's mill there is a fall from that mill to the main river equal to the fall at Lord UxBRIDGE's mill, which being measured the same day was 5 seet 6 inches, the greatest part of which perpendicular descent may be added

to that of Hubbert's mill-fall, without affecting any other; that is, by straightening, widening, and deepening the said tail-water course from the main river to Hubbert's mill.

Now this being done in a moderate degree, will add 4 feet to the fall of Hubbert's mill, and still leave 18 inches for the declivity of the tail-stream; in which case, the quantity raised will be greater than before; that is, instead of 2517 hogsheads raised per hour, the quantity of 4138 hogsheads will be raised in the same time; but by a still greater enlargement of the tail-stream to about a 15 feet bottom, brought upon a dead level at the depth of 11½ feet below Hubbert's mill sull head mark, it is practicable to add 5 feet to Hubbert's mill-sall, leaving only ½ a foot declivity in the tail-stream, in which case the quantity raised per hour will be 4482 hogsheads.

At other heights the quantities that may be raised are expressed in the following table.

It is further to be noted, that, according to the information of the millers, the river Coln in the drieft seasons is not less than half of what it was upon the day abovementioned; so that Hubbert's mill can then go at least half its time, and with the supply above specified; but by information that Mr. Fordyce afterwards procured, they never are obliged to stop above 7 hours in 24.

The drieft months, it feems, are August, September, and October, so that as the scarcest time for water is when there is the least occasion for it at London, and as we may reckon upon a constant supply during the winter and spring months equal to what is above set forth, that is, during all such times as the town is sully inhabited, it sollows that we may, in effect, compute upon the same supply throughout the year.

The whole quantity of water current in the river Coln, at the time abovementioned, was afcertained, by observing that two waste gates at Lord Uxbridge's mill being drawn, at that time discharged the currency of the main stream, the dimensions of the openings of those gates being taken, the quantity of water issuing was from thence computed; this, added to the quantity discharged by the bye stream at Hubbert's mill, constitutes the whole quantity, amounting to 10463 cube seet per minute, that is of 73978 hogsheads per hour, produced by the river Coln: the proportionable quantity thereof proposed to be taken into the new canal, is set forth in the following table, according to the different quantities that a different fall at the mill, and height to which it is to be raised, will be produceable of, and is contained in the last column.

A TABLE,

A TABLE, shewing the quantities of water capable of being raised at Hub-BERT's mill, according to the different heads or falls, and according to diffeferent perpendicular heights to which it is required to be raised.

	or fall of ater.	Perpendicular height to be raifed above the mill head.	Quanti	ity raife	Proportionable quantity taken to that of the river Coln, Feb. 23, 1766.	
Feet.	Inches.	Feet.	Cube feet.		Hogsheads of 52 ale gallons.	
5	7	20	356	==	2517	i full
9	7	20	585,3	=	4138	The full
10	7	20	634	=	4482	TE scarce
10	7	15	788,3	=	5573	t fcarce
10	7	10	1024,8	=	7246	To fcarce
10	7	8 1	1125	_ =	7954	t scarce.

London, March 10th, 1766.

J. SMEATON.

P. S. Four Hogsheads as above make a ton liquid.

# CORN MILL at WORKSOP.

The REPORT of John Smeaton, Engineer, concerning the practicability of erecting a Corn Mill, to be worked from the farm-yard pond, at Worksop Manor:

THE fall from the surface of the farm-yard pond to the surface of the canal, in the new menagerie, is 9 feet 6 inches, which is a sufficient fall for the erection of a mill; the principal difficulty, therefore, attending this affair, is to supply the said pond with water, sufficient to answer the intended purpose.

The quantity of water necessary depends upon the quantity of corn to be ground, which was stated to me at 10 loads per week, that is 30 Winchester bushels.

The quantity of water necessary to grind one bushel of wheat into flour, will grind five quarters of malt, so that supposing 10 quarters of malt to be brewed per week, the quantity of water that is necessary to grind 32 bushels of wheat per week will dispatch the whole business.

Now 3600 cube feet of water will, in this situation, be required to grind one bushel of wheat, and therefore 115200 cube feet will be necessary to grind 32 bushels; and this quantity, at least, must be supplied to the farm-yard pond in a week.

	Cube feet.
The overflowing of the pond at Steetly amount to, per week,	40019
A fpring rifing somewhat below, but which, together with Steelly overflowings, may be brought	
to the farm-yard pond,	15120
The pipes from Steady, at 5 hogsheads per hour, which they are faid to run, gives 1018 cube	:
feet per day, 3 of which I suppose will directly, or indirectly, come into the pond, amount-	
ing, per week, to	4751
The engine put in order, and the pipes repaired, as it now stands, will raise into the sarm-yard	
pond per week,	2.1080
Total of the above, per week,	83970
The aggregate of the quantities before mentioned,	83970
The quantity required,	115300
Deficient -	31230

The power 83970 cube feet is fufficient for grinding  $23\frac{1}{2}$  bushels, that is, besides grinding 10 quarters of malt, it will grind  $21\frac{1}{2}$  bushels of wheat, or about 7 loads; but this is not supposed enough, though there is no allowance made for waste.

Coldwell Spring, having been carefully levelled, has been found to rife 6 feet nearly higher than the furface of the farm yard pond, when that furface was  $9\frac{1}{2}$  feet above the canal of the New Menagarie.

The course for an aqueduct has also been traced out, and though it will be almost miles in length, yet this spring may be thereby conducted, upon a sufficient declivity, to fall into the sarm yard pond.

Coldwell Spring being gauged in the month of March, 1766, then afforded 161280 cube feet of water per week, a quantity capable of grinding near 45 bushels of wheat; so that here we shall have 46080 cube feet of water per week to spare, or to allow for waste, and what the spring may afford less in dry seasons; but as it is said to be nearly the same in the driest seasons as when it was measured, we may safely reckon upon the whole quantity as above specified; nay, considerably more, because the defects will be more than made up, by taking in the brook that runs by the Coldwell Spring, which, at the time of measuring, was nearly equal to the spring, and in the driest season is said to run half as much; but if we reckon it only \frac{1}{2} as much, viz. 53760 cube feet per week, we shall then have a surplusage upon the whole of 99840 feet per week, which is almost \frac{1}{2} of the whole quantity sound necessary.

Here, then, is a sufficient source of power not only effectually to answer the present purpose, but others also that may occur, and which in so large a family, may, in all probability, be very usefully applied.

As this spring is alone sufficient to answer the end, it would hardly seem a question which ought to be preferred; but as an aqueduct for Coldwell Spring will pass through rocky ground, in one part at the depth of 15 feet, and which, at a medium, will hold nearly of a mile, this, with some other dissipulties, particularly the carrying it up the north lawn from the road, which being supposed a running sand, will be troublesome to dig, and will otherwise require arching; those impediments will induce a considerate dig, and will otherwise require arching; those impediments will induce a considerable extra expence; so that to overcome all probable difficulties, and to make the whole of proper dimensions and strength, will require the sum of 4001, to be expended upon it.

Kk

The

The deficiency of the former aggregates may, however, probably be made good by taking in the brook last mentioned: the particular observation was not made at the time, but, from the nature of the thing, it must be supposed that the water of this brook may be intercepted at such a level as to be conducted over the principal impediments that affect the Coldwell course, and consequently can be carried into the same yard pond, together with the water from Steetly, &c. now, if we recken, as before, upon 's of the Coldwell quantity for this brook in dry seasons, we have 53760 to be added to the former aggregate of 83970, which together amount to 137730 cube feet per week, which affords a surplusage of 1050. This, however, is but barely sufficient to allow for waste, even if all the quantities held out in summer what they have been supposed from observations at the same time as those on Coldwell Spring were taken.

This aggregate scheme may probably be brought to bear for 1501, if not 2001, less than the Coldwell aqueduct; yet, as a material part of the supply depends on the performance of the engine, this, if out of order, will render the mill desective also. The certainty of success, therefore, attending the Coldwell aqueduct, and the permanency of the benefits arising therefrom, as depending wholly on natural causes, being considered, as every other part of the work will be the same, whichever way supplied with water, it seems that the value of 1501, or even 2001, saved in the first erection will no ways counterbalance the superior degree of certainty attending the other scheme, as well as the surther advantages that may probably be drawn from a superior supply of water.

A further and substantial argument for executing the Coldwell aqueduct is, that by means thereof the whole of the waters mentioned may be united at a final addition of charge; so that by this means, exclusive of the engine, and after deducting 1 of the whole quantity for waste, we shall have remaining a neat natural power of 240564 cube feet of water per week, a quantity capable of grinding  $66\frac{3}{4}$  bushels, that is, above 22 loads of corn, being more than double the power required; to that, after serving very useful and valuable domestic purposes, in passing from the turm-yard pond to the canal of the new menagerie, it will there surnish a fine supply of water for the cascade in falling from the upper canal to the lower.

I have mentioned 4001, as the probable expence of an aqueduct from Goldwell Spring to the farm-yard pond, which furn is drawn from an estimate made from such observations as have already been collected, and is intended to give the best idea of the expence that I can at present: and I also reckon that the mill-work, together with build-

ing, the alterations that will be necessary in the farm-yard pond, and the drain that will be necessary for conveying the mill's water to the canal of the new menagerie, will cost 4001, more. If, therefore, it is not thought worth while to execute the scheme at the expence of 8001. I would not advise to proceed upon it; but if so, then I shall be ready to make such further observations as the former have suggested, in order to make out a particular plan of the whole, from which a more exact computation may be drawn.

J. SMEATON,

Newcastle, May 12, 1766.

## SPURN POINT LIGHTS.

DESCRIPTION of the Machine for supporting the temporary Lights to be erected at the Spurn Point.

AB is the round pan, cage, or basket of iron, wherein the coal fire is made, to be 18 inches diameter, and 18 inches deep for the great light, and 16 by 16 for the lesser light, a little tapering towards the bottom.

CD is the mast for supporting the cage, at the height of 50 seet above the ground for the great light, and 35 seet above ditto for the lesser. The mast is hung up on an iron axis E at the height of  $22\frac{1}{2}$  seet above the ground, and consequently  $27\frac{1}{2}$  seet below the center of the greater light, by means of which axis the fire-pan is brought down sufficiently near the ground to supply the same with sue; the fire-pan turning upon an axis of its own or swivel, so as to keep it upright in every position of the mast.

F is the stone, of sufficient weight with the butt end of the mast, to balance the sire-pan, coals and iron-work at the other end, that it may turn freely, and in moderate weather be hauled down and up by hand of one man by means of two ropes, one sastened near the upper end, the other at the lower end of the mast, the stone to be hooped to prevent its splitting.

GG is a roller with winches, to which the ropes aforefaid being respectively applied with hooks for the more ready fastening to the staples in the roller, the mast will be managed in hauling down and up also by one man in the most stormy weather.

HH is a fixed piece of wood with a semicircular hollow, to which the lower end of the mast applies itself when in an upright position, and when necessary is retained therein by an half circular keeper, plate, or class of iron.

as the great axis of the mast, is supported upon two upright posts 22 feet 4 inches above ground, and 3 feet within ground, framed into groundsills at the bottom, and each post braced in three directions; the feet of the braces to be framed into the groundsills, and all the bearings supported by piles underneath, disposed as per plan.

IK are the two upright posts.

Vol.1.p.251 MACHINE for supporting the TEMPORARY LIGHT to be erected at SPURN POINT. ELEVATION ELEVATION FRONT SIDE Published as the the devets the by Lempines Burst Reis there and Brown Paternaster Box London.

LMN are three braces belonging to the post I, and

 $OP \mathcal{Q}$  are the braces belonging to the post K.

In order to keep the tops of the posts at a still more certain distance, the ends of the axis are to be finished each by a knob, to lay upon the outside of the bearing crutches or brasses, which will hinder the tops of the posts from slying out, and on the out ends of the knobs iron studs are to be driven into the top of the posts, which will keep them from coming together, the axis acting as a stretcher. The tops of the posts are to be hooped, the more effectually to fix the work thereon, and covered each with an iron plate to defend them from the hot cinders.

R is a pulley in order to fet the rope at a proper distance for hauling down the mast by the windlass roll; this rope is to be annexed to about two yards of small chain fixed at the point b; such as is made for the smallest size of horse traces, will be strong enough.

S is an umbrella made of thin boards, to prevent coals, &c. from falling upon the person working at the roller, the pulley R is set at a distance in order that the rope for hauling down the mast may have the better purchase upon it when upright; where note, that this rope being fixed to the mast at b, when the pan is down, and the point c brought down to the point c, then the point b will come to the point f, and the tail of the mast will be at the point g, and the line G g will be the direction of the rope when it begins to act from the roller upon the tail of the mast, in order to hoist up the sire-pan, and set it upright.

N. B. The balance of the whole is to be so adjusted, that when the pan is sull of coals, the head of the mast will be heaviest, but when the fire is burnt low then the head of the mast shall be lightest.

The same letters refer to the same thing in all the figures.

The measures set down in figures refer to the greater light, but the measures will be given for the lesser light, by taking off the respective parts from the scale belonging to the lesser, which will give every thing in proportion to their respective heights.

## Directions for the smith.

It is to be observed that the fire-pan, with fork or crutch for supporting it, as well as all the iron-work at the mast head, is to be made as light as possible, consistent with the necessary

LMN are three braces belonging to the post I, and

OPQ are the braces belonging to the post K.

In order to keep the tops of the posts at a still more certain distance, the ends of the axis are to be finished each by a knob, to lay upon the outside of the bearing crutches or brasses, which will hinder the tops of the posts from slying out, and on the out ends of the knobs iron studs are to be driven into the top of the posts, which will keep them from coming together, the axis acting as a stretcher. The tops of the posts are to be hooped, the more effectually to fix the work thereon, and covered each with an iron plate to defend them from the hot cinders.

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N. B. The balance of the whole is to be so adjusted, that when the pan is full of coals, the head of the mast will be heaviest, but when the fire is burnt low then the head of the mast shall be lightest.

The same letters refer to the same thing in all the figures.

The measures set down in figures refer to the greater light, but the measures will be given for the lesser light, by taking off the respective parts from the scale belonging to the lesser, which will give every thing in proportion to their respective heights.

# Directions for the fmith.

It is to be observed that the fire-pan, with fork or crutch for supporting it, as well as all the iron-work at the mast head, is to be made as light as possible, consistent with the necessary

necessary degree of strength;  $1\frac{1}{2}$  inch diameter will be sufficient for the two branches of the fork near their joining, and tapered to  $1\frac{1}{4}$  near the holes for the axis on which the pan hangs, the rest in proportion; the whole to be made as short as possible between the top point of the wood of the mast and the axis, whereon the fire-pan hangs. It is also to be observed that the fire-pan axis projects 6 inches on a side beyond the ring, and that an iron strap be brought up from each side the bottom of the pan, and connected to the ends of the axis, as shewn in the front elevation, in order to prevent the axis from sagging by the heat of the sire. It must also be observed to make the round gudgeons of the fire-pan axis not above  $\frac{7}{3}$  of an inch diameter in the round part, but the holes at least  $1\frac{1}{3}$  or  $1\frac{1}{2}$ , and the gudgeons long enough that they may not jamb tast, or draw out by a little bending or sagging; one of the holes must also be made to open in order to change the pan occasionally, as repairs may require.

ç c is the fire-pan's axis.

dd the two traps from the bottom.

EXPLANATORY Remarks and Observations upon the designs for building the Light-houses upon the Spurn Point, as approved of by the Honourable Corporation of Trinity-House, Deptford Strond, London.

#### No. 1. The general plan.

As the present variation of the compass at the Spurn Point is not exactly known, in case it should be found to differ from that supposed in this plan, viz. 20 degrees westerly, the direction of the light-houses in respect to one another are to be placed S. E. and N. W. by the compass, and the windows, &c. of the buildings to be placed according to the true meridian.

## No. 2. The section and elevation of the great light-house.

The top of the stone setting or pitching of the soundation is herein supposed to be about 3 seet 6 inches below the general surface of the ground, from whence the height of 90 seet to the center of the lanthorn is taken; but as it is intended that the said setting shall rest upon the bed of gravel or shingle underneath the upper stratum of sand, the

depth of the foundation may be a little varied, according to the depth at which the gravel is found, so as to give the foundation a greater degree of folidity. The length of the piles may also be varied if they cannot be got down to the length specified, or in case they drive too easily to that depth.

In the fection,  $\Lambda$  shews a pipe or passage-hole for the sacks of coals, from the coal-vault to the lanthorn, to be drawn up by the machine B, which also serves for drawing up the sacks of coals that are brought in carts from the waterside into the door F, by means of the small gibbet at C, from whence they are to be poured down into the vault by the trap-door D, when filled too high, to open the door E.

G is a pipe for bringing down the ashes.

N. B. The jaumbs of the doors are supposed in the estimate to be of stone.

No. 3. Section of the lanthorn pipe room.

The receptacle for the ashes, both bottom and sides, for  $4\frac{1}{2}$  seet in height, are supposed to be compleatly lined with plate iron of  $\frac{1}{12}$  of an inch thick, to prevent the hot cinders and ashes from burning the wooden case; the door must be made as tight as possible.

Between the stone covers of the air tunnels a a other stones are to be introduced, though not shewn on the outside, so as to compleat a circle of stones, which are to be well crampt together, in order to form a chain course for the springing of the brick arch thereupon.

B B are large bellows, to serve when the wind does not blow strong enough.

C is a tunnel and ash-pipe, for the speedy conveying the ashes and cinders to the outside of the bottom of the house, when the receptacle is emptied, as it ought to be every day.

D, air-holes in each face of the lanthorns, to be stopped or unstopped with sliders, in order to prevent the lanthorn from smoaking.

The hearth and floors of the lanthorn and balcony, together with the balconent of the lanthorn, to be of flone; the roof and chimney to be of four-inch Elland edge flags, properly mitted together; the balcony rails to be of iron.

No. 4.

Where, in the plan, A is the paffage or door-way up into the lanthorn, B the cover for the fack-hole.

At a is a hole for the rope to go down to the machine for hoisting the facks, to be returned over pullies in the upper part of the lanthorn, so as to answer to the middle of the fack-hole.

b is a hole for a rope from the bellows, which, being returned in like manner over pullies, may go down into the pipe-room by the hole marked c, so as occasionally to be blown there as well as in the lanthorn, in case that in summer time the lanthorn shall prove too hot.

In the section, C shews the place of the sack-hole.

d is a multiplying wheel and axle for working the bellows with ropes instead of a lever, which in this place would be inconvenient, especially when the person working them is in the lanthorn, as in general he is supposed to be.

N. B. The bellows are supposed to be made square, in the way of organ bellows, but with neat's leather, and nailed together.

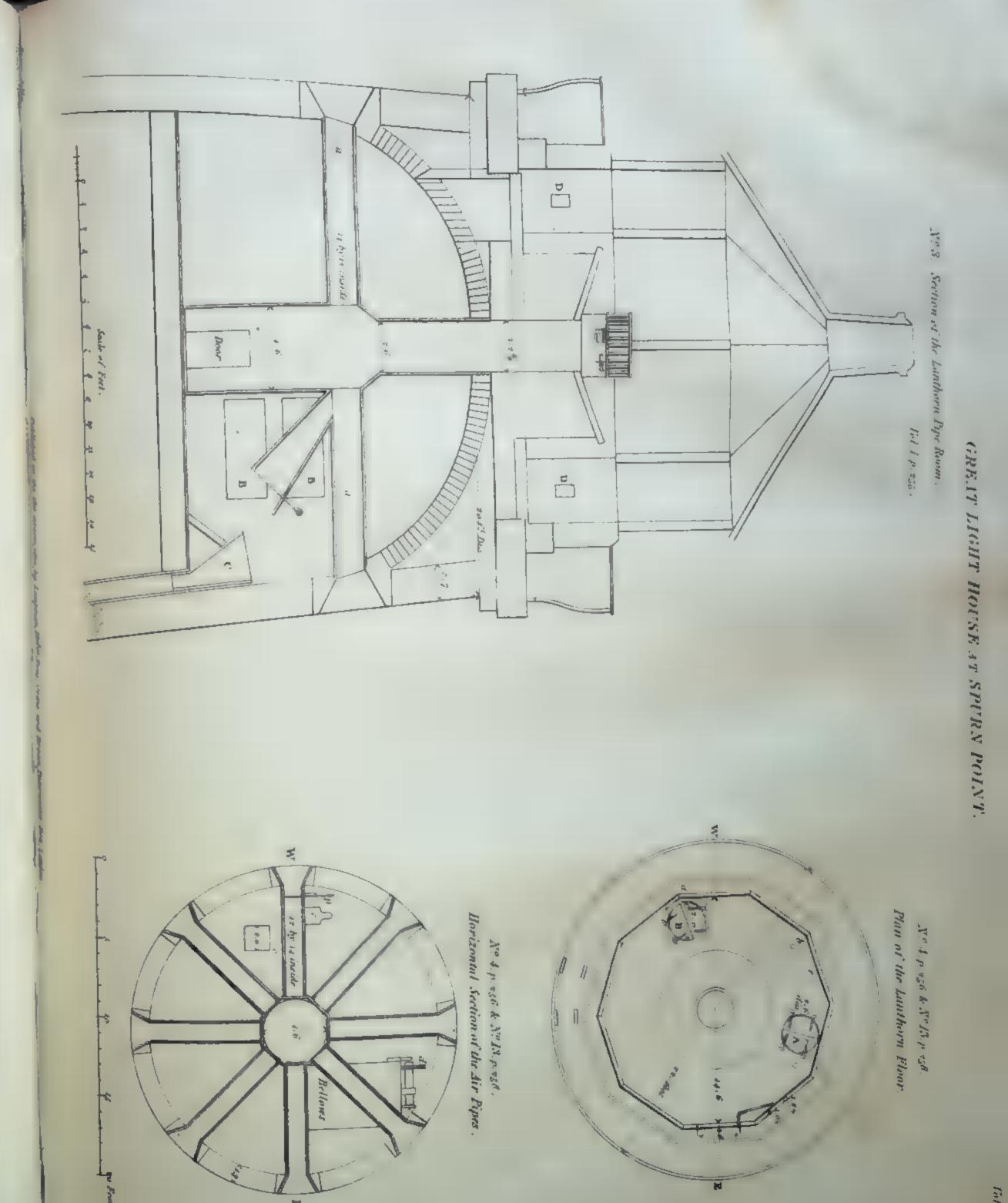
e shews the flat of a slider, and g is the same in its proper position; each air-pipe to have one, in order to open any of them at pleasure, and regulate the sorce of the wind when too strong.

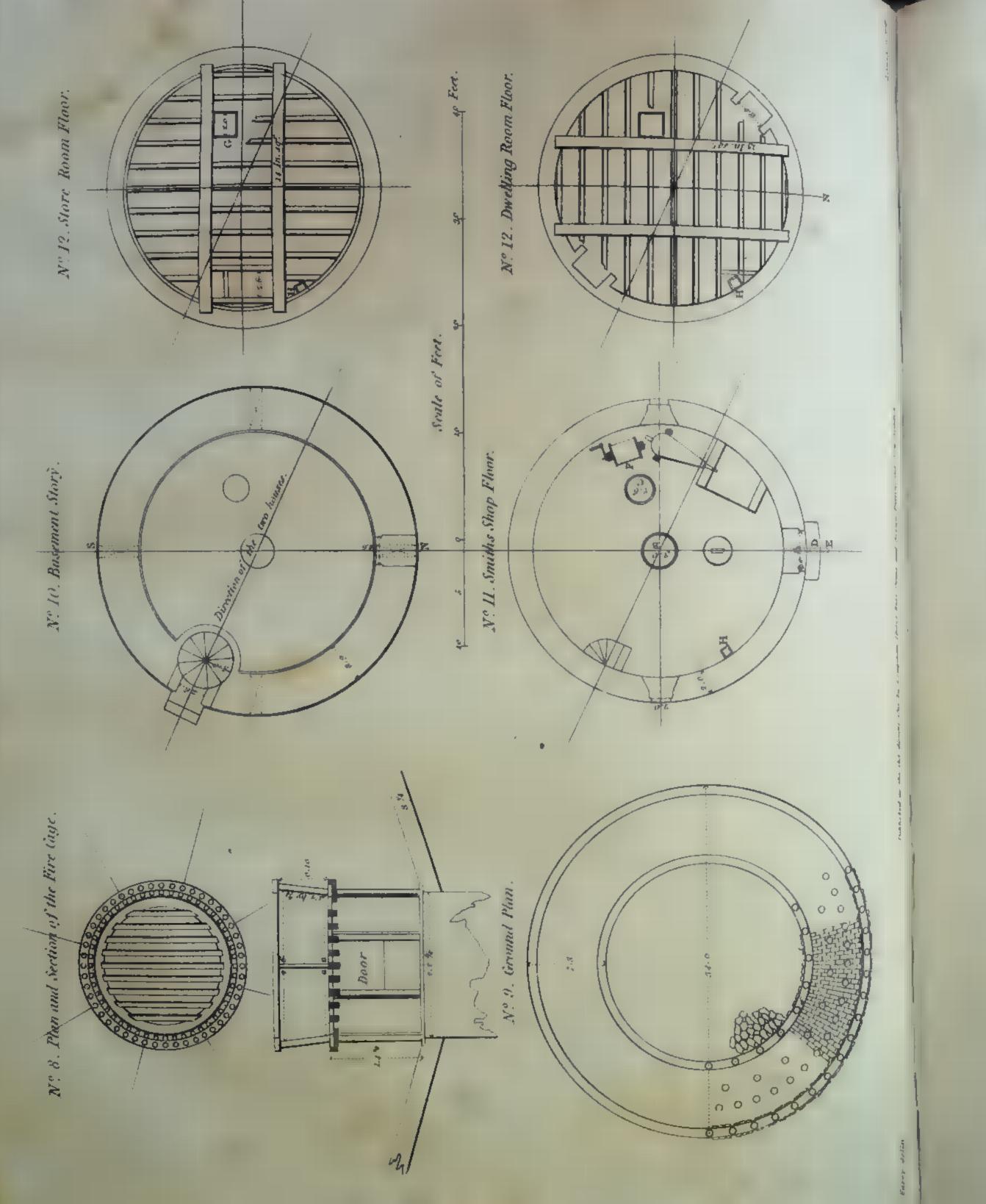
N. B. In order to give the wind its full force, 2 or 3 of them to the windward to be open, and all the rest closed, and when the bellows are used, to be all closed.

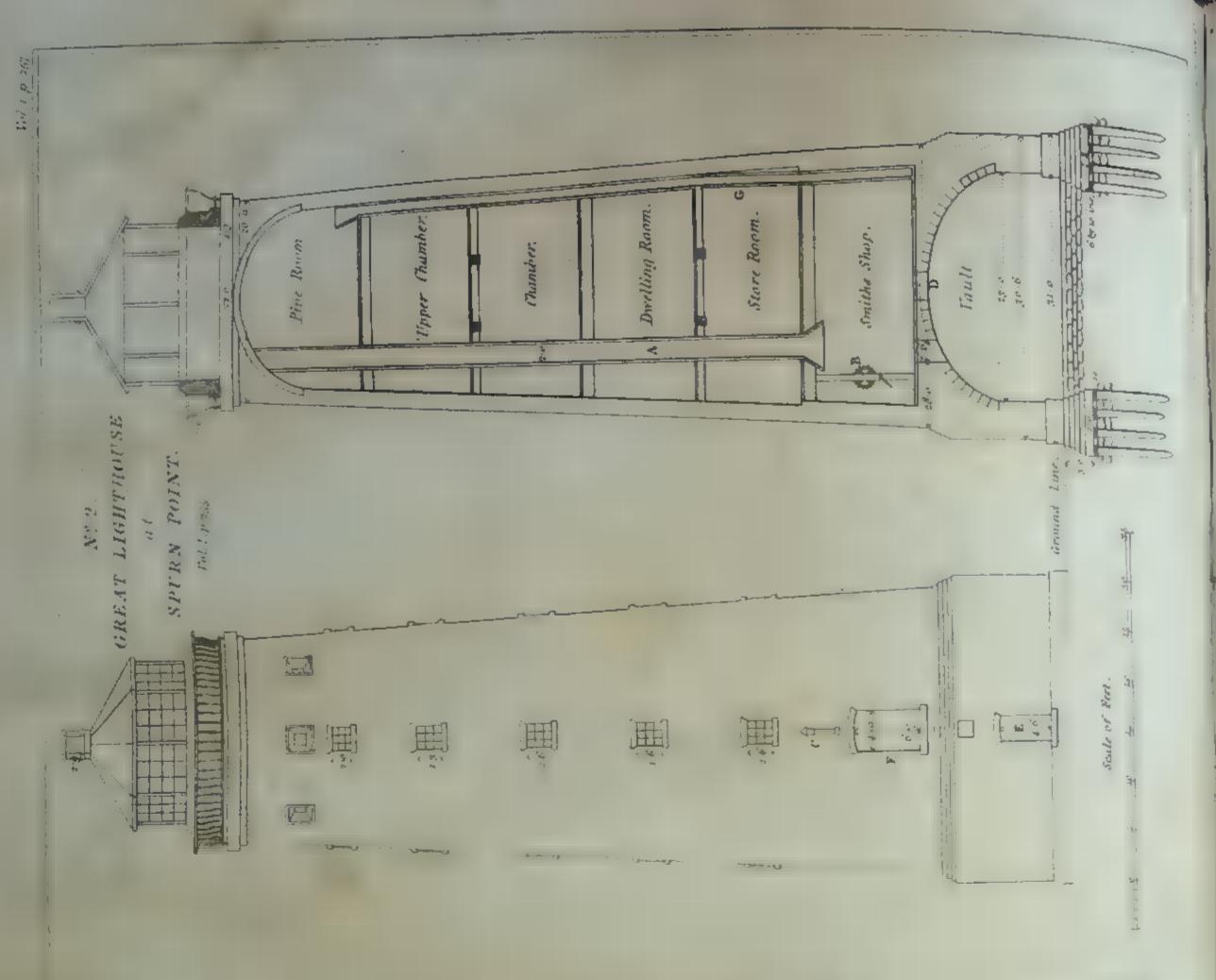
No. 5. Plan and upright of one of the window-frames for the lanthorn,

Wherein the upright AA shews two of the upright pillars or stanchions to be of cast iron.

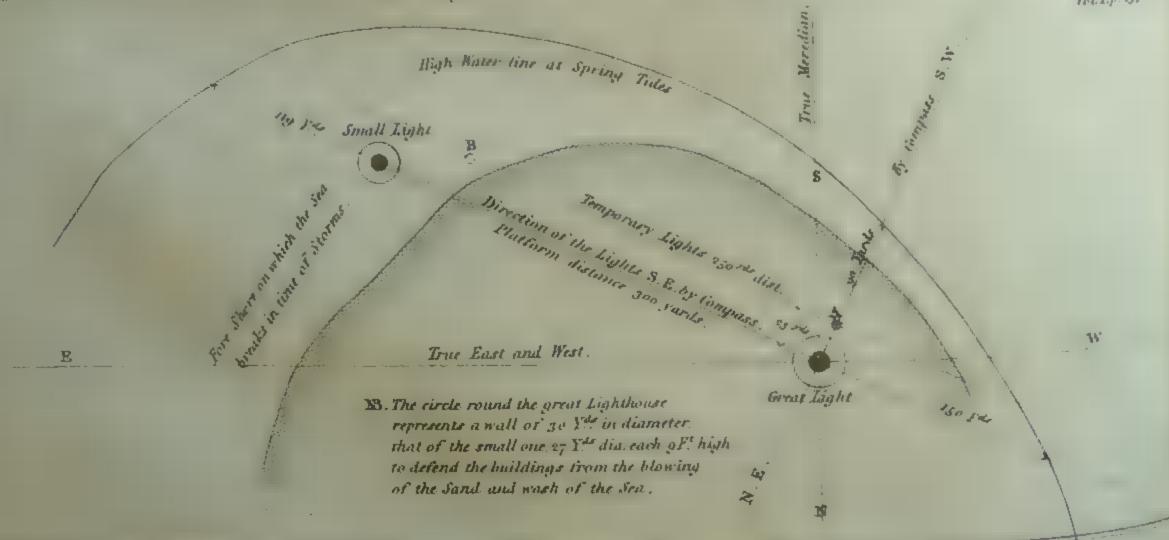
a a the fell, and b b the plating of strong iron bars, by which the pillars are connected; the window-frame is to be of wood, but strengthened by a bar of iron, laying within the middle horizontal bar, and screwed thereto, as represented in the plan at 66 6.







Nº 1: GENERAL PLAN of the Situation, Bearings, Distances &c of the LIGHT HOUSES to be erected on SPURN POINT.



# No. 6. The section and elevation of the small light-house.

As this light-house is to be constructed upon similar principles with that of the great one, and the difference of dimensions being assigned by this general design, it is presumed that a more particular description of the parts will be unnecessary, when reference
is had to what precedes and succeeds relative to the great one.

No. 7. Design for one of the ten iron stanchions that form the windows, and support the roof of the lanthorn, drawn at large.

This, with reference to what is explained concerning No. 5, will be sufficiently clear from what is upon the face thereof.

No. 8. Plan and section of the fire-cage and hearth.

This is supposed to be sufficiently explained with what is upon the face thereof.

#### No. 9. Plan of the foundation.

Upon the outward and inward circles of piles a kirb of wood is to be nailed down upon their heads, which are first to be cut level; but before the kirbs of wood are fixed down, the whole intermediate space between the piles is to be pitched or set with Elland edge setters, of 9 inches in depth, set edgeways, in the manner the streets are paved about Itallisax; those are to be well rammed down with a two-man rammer in in the manner of a pavement, taking care that those setters that will be covered by the kirbs may be somewhat suller than the pile heads, that the kirbs may take their bearings equally upon the setters as upon the piles: this done, the joints must be run sull of grout, made of lime and sand made shuid with a proper quantity of water, which done the brick-work must be carried on thereupon as shewn in No. 2.

### No. 10. Plan of the vault or basement story.

This is a plan of the vault at the top of the plinth or set-off above ground; the rest will sufficiently appear by reference to No. 2.

# No. 11. Smith's shop stoor and store-room stoor,

Wherein the smith's shop floor A shews the great door, D the projecting landing-place, E the gibbet, F the machine or winch for hoising the coals, B the hatchway for shooting the coals down into the vault, which being in the middle will be equally distri-

distributed, C the hatchway for the sacks to go up into the lanthorn, answerable to the sack-hole or pipe described No. 2. H shews the place of the ash-pipe.

In the plan of the store room stoor, G is the sack-hole, and H the ssh-pipe, the east and west windows blank.

N. B. The doorway or hatchway had better be nearer the wall, as well in this as in the floors above.

No. 12. The dwelling-room floor and chamber-floor.

After what has been remarked on No. 11. it is only necessary to observe that there being two opposite chimnies in the dwelling-room, they may be used the one or the other as best suits the wind; in the chamber-stoor the north and west windows are supposed blank.

No. 13. The upper chamber-floor and pipe-room floor

Will be sufficiently explained from what has been already remarked, the north and west windows in the upper chamber being supposed blank as in the chamber below, the pipe-room windows all open.

J. SMEATON.

The foregoing explanatory observations were sent to London for the approbation of the Corporation of Trinity House, a copy of which was by them returned, in order to be returned to Mr. Thompson in their Common Seal, to which was subjoined the following.

"Trinity-House, London, March 21, 1767.

rew light-houses to be erected at the Spurn Point, the Master, Wardens and Assistants of the Corporation of Trinity House of Deptsord Strond, do hereby, under their Common Seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

By order of the faid Corporation,

CHARLES WILDBORE, Clerk."

ESTIMATE of the expence of building two Light-houses, with proper conveniencies, upon the Spurn Point, as designed by John Smeaton, Engineer, from the orders and directions of the Honourable Corporation of Trinity-House of Deptsord Strond.

### Estimate of the great Light-house.

			£, s.	. d.	
To casting, piling, and setting the foundation, as per plan,	-	88	123 1	0 0	
To brick-work in the building,	-	-	48z 1	3 1	
To flone-work in ditto,	-	-	201 1	4 0	
To Ronc-work in ditto	-	-	249	3 4	
To carpenters work in ditto,	100 I4	4			
To iron-work in the lanthorn,	65 6				
To ditto in the balcony rans,	30 8				
To ditto in the fire-place, with z cages,	62 15	4			
To ditto in the building,		_			
			259	4	4
Total of iron-work,	56 19	3			
To plumbers-work, covering the balcony floor with lead,	15 6				
To ditto in eistern and pipes to bring rain-water from the roof,		-			
			72	5	3
Total of plumbers-work,	5 0	0			
To glazing the windows of the rooms,	-	0			
To ditto in the lanthorn,	10 3	_			
10 dieco			17	5	0
Total of glaziers-work,					
10tat of Subsection			1405	15	0
Great light-house,					
Great it guestions			1405	15	0
The great light-house, as per estimate,			1054	6	0
The great light-house, as per elimated, The small light-house, estimated at 3 of the expence of the great one,	-		. 00		0
The (mail light-house, carming the two houses,		II dont	-		
The stone platform between the two houses,  The stone platform between the two houses,  The brick wall round the greater light-house, 30 yards diameter, with carr	rage and ima	III GOOL	118	12	0
The brick wall round the greater age	. 0'1	diva	118		0
and capped with thone,  Ditto round the small light-house, 27 yards diameter, but being more expose	d, estimated s	at anto			
Ditto round the fmall light-noune, 27 juices			2787	ς	0
			-1 -1		
To the above allow for accidents, contingencies, and difficulty of fituation	n, 10 per cer	it. upon	278	10	0
To the above allow for accidents, contingential	-	1	2/0	.,	
the whole,			3066	0	0
			3000		
		50.1			
	ours of fure	VIIII.			

N. B. Nothing is allowed in the above estimate on account of supervisal.

This estimate was authenticated by the board, under their common seal, and with the following testimony:

This Estimate of the expence of erecting two new light-houses on the Spurn Point, the Master, Warden, and Assistants of the Corporation of Trinity-House of Deptsord Strond, do hereby, under their common seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

By order of the faid Corporation,

CHARLES WILDBORE, Clerk."

Trinity-House, February 21, 1767.

(Duplicate. C. W.)

ADDITIONAL Remarks and Observations, touching the construction of the Light-houses upon the Spurn Point, as approved of by the Honourable Corporation of Trinity-House, Deptsord Strond, London.

Design No. 1. Being the general plan.

It is mentioned that the light-houses are to be placed at the distance of 300 yards center and center, and in a direction S. E. and N. W. by the compass, in respect to each other; to be joined by a platform of stone, the construction of which I proposed to be as follows:

To be composed of *Elland Edge* natural-faced slags, 2 feet in breadth and 4 inches thick; to be supported by a pavement or setting of brick on the edge, and 3 bricks lengths wide, to be well beat down with a paviour's rammer, the ground being first levelled and consolidated by ramming: the hand-rail to be  $3\frac{1}{2}$  inches square, supported by posts of  $4\frac{1}{2}$  inches and 6 feet long, set in the ground, so that the rail may not be more than 3 feet above the surface of the slagging. This timber is supposed to be of Riga sir.

The circular brick wall round the great light-house, said to be 30 yards diameter, that is, out and out, I propose to sound at the depth of 3 seet, or thereabouts, below the mean surface of the ground, but if at a less depth, a stratum of gravel can be found tolerably compact to sound upon it. The bottom, when opened, to be consolidated

lidated by ramming, and the first ground course to be 3 bricks length broad, set upon the edge and driven down like a pavement; then two courses upon it to be laid flatways, as common, in mortar, of  $2\frac{1}{2}$  bricks wide; then to be carried up of two bricks till a foot above the ground; then to be raised to 8 feet 1 inches high above ground, and to be capped with stone 4 inches thick: this, if the undertaker chuses, may be of Elland edge slagging, with the natural saces, but hewn true to 1 joint and regular border; or with any other kind of stone, such as used about the light-houses, that will bear the weather: the capping to project about 2 inches on each side, and to drip towards the outside, to be laid on with mortar made of lime from Barrow, in Leicester-shire, or any other lime of equal quality for water-works. The body of the wall to be built with lime from Houghton, near Castleford, Yorkshire, or any other of equal quality.

The small light-house circular wall to be sounded as the sormer, but the mortar courses on the 3 bricks length on edge setting; to be raised  $2\frac{1}{2}$  bricks thick to 1 soot above ground, and then a bricks to 8 seet 8 inches above ground, and covered with 4 inch capping like the sormer, without any projection on the outside, and about 2 inches within, but laid so as to drip outwards, the outside brick breadth to be walled, and the capping to be laid on with Barrow lime, and the rest walled with Houghton, and both walls to be grouted or run with liquid mortar every sour courses.

The area of these two courses between the light-houses and the out-walls should be paved with good bowlers, so as to resist the wheels of carriages carrying coals. This article has not been particularly considered in my original estimate, otherwise than in the articles of contingencies.

Design No. 2. Being the section and elevation of the great Light-house.

The external and internal circle of piles in the foundations are, as drawn, intended to be 10 feet long, and 10 inches diameter at the heads, and the internal piling of 9 feet long, and 9 inches diameter at the heads; but both these dimensions to be varied according as the ground proves on trying it with piles: the piles here supposed are of oak, elm, beech, or alder, but may be of Riga sir, or any other kind of red wood fir of equal quality for duration under ground, in which case, if square 9 inches will do for the kirbs, and 8 inches square for the internal piling, the length being supposed the same as before.

The thickness of that part of the shell of brick-work marked 2 feet, is supposed 3½ bricks, and that marked 1 soot 7 inches of 2 bricks thick; the bricks in the north being

being made larger than those in the south, it was supposed they might probably in walling make those thicknesses specified, but at the same time it was not proposed to have bricks made on purpose, but to be walled with the common size of bricks usually made in that part of the country, but they should not be less than the statute thickness for London; and, N. B. wherever a difference in the dimensions of the bricks, the thicknesses assigned to the several parts cannot exactly taily; it is the outside measure which is to be preferved, unless particularly directed to the contrary. The fort of bricks proposed to be used is what in the north are called water-bricks, in contradistinction to stock-bricks, but those to be particularly hard and well burnt.

It was proposed to build the whole with Houghton lime, or other good stone lime of equal quality; but I am of opinion, that, considering the exposure of the situation, it will answer a better purpose to have the outside bricks in breadth walled with Barrow lime, leaving the undertaker to make use of what lime he chuses for the internal parts of the wall, being stone lime good in its kind, and well tempered; and that it will be better to allow the undertaker whatever difference there may be in the value of both forts together, if any, when used instead of Heughten lime for the whole, than that this precaution should be neglected. The whole of the inside to be walled fair, and to be grouted at every fourth course. The undertaker to be allowed to use, if he pleases, either sea water, or such as can be obtained by digging a well upon the spot, as he shall chuse; and to prevent any damp in the dwelling-room it will be proper to be stoothed, lathed, and plaistered, (the plaister being made up with fresh water) which will be a far more effectual desence against damp, than any difference that can arise from the quality of the water in the out-walls, having found that good mortar binds as well with falt water as fresh.

N.B. This article of stoothing and plaistering was not considered in the original estimate.

In regard to the stone-work, all the parts that require large stat stones will be best supplied from Elland-Edge, or from Cromwell Bottom quarries, which are of the same quality; but in regard to the stone-work for door-cases, window-sills, steps, the air-pipe mouths, and girdle stones, to compleat and cramp that course together, with the mutules and facia composing the balcony floor and basement of the lanthorn, as there are a number of good quarries in the neighbourhood of Aire, Calder, and Dun, as well as at Sunderland, which afford the proper materials, the undertaker should have the choice of getting them where he can serve himself with most advantage, being obliged to furnish good strong stone, and such as will endure the weather.

Instead of lintells on the insides of the doors and windows, they are proposed to be arched with brick.

The timber every where to be made use of is supposed to be the best Riga fir, or other red wood fir of equal quality, for the respective purposes, except where the fort of wood is particularly expressed to be of a different kind. The doors between room and room are proposed to be trap-doors, and the ascent between room and room to be strong step ladders of equal width with the door-ways, the sides to be at least 8 inches by 11, and the steps not to exceed 8 inches rife, and the ladders not to stand steeper than an angle of 45 degrees where the place will properly allow it.

The windows of the rooms to be of clean well feafoned English oak; they are defigned to be simply a frame, whose outside circumference is 3 inches by 2, and the inside bars of stuff  $1\frac{1}{2}$  by 2 inches; they are to be fixed up against a check made by the projection of the outward bricks, and fastened by a pin, so that the whole frame may be taken out at pleasure, in order to air and ventilate the rooms, when occasion shall require, and the weather admit: there is a small error in the original drawings, in regard to the manner of forming the window-fole stones, wherein the check is represented on the outside, and that, for the sake of keeping out and venting the wet, ought to be within; and as this matter cannot be so easily described in words as to prevent ail uncertainty, I have added a drawing, intituled No. 14, wherein the particulars are expressed more at large. The glazing of all the room windows supposed to be of common glass; the clear opening of all the windows, when the frames are out, is 2 feet wide by 2 feet 6 inches high, the pipe-room windows excepted, which are to be 2 feet wide by 2 feet high.

Their number will be as follows:

E. W. and N. In the fmith's shop, N. and S. In the store-room, In the dwelling-room, E. W. N. and S. N. and S. In the chamber, N. and S. In the upper chamber, E. W. N.S. In the pipe-room,

All the rest blanks, with arches and sole stones to preserve the regularity on the outlide, and to be opened afterwards, if need should happen to require.

Designs, being No. 3 and 4, being sections and plans of the lanthorn and pipe room.

Upon No. 3 I observe, that the windows may, with more advantage, be placed two course of bricks higher, or nearer the pipe mouth-holes, that above the proposed lining with plate iron; of the receptable for the arches, it will, for further fecurity, be proper to line the whole infide of the wood-work, composing the upright tube, with double tin-plate, and to extend the same the breadth of a tin-plate within the air-pipes.

The stones mentioned to be laid between the pipe-mouth stones, marked a a, in order to form a chain course, are supposed to lay upon the same bed as the cap-stones of the air-holes, and to reach to the outside, wanting only one brick's breadth, that is, they will be 1 foot 6 inches up and down, and 1 foot 9 inches inside and out, at the extreme breadth: the whole of this course to be of stone of a firm quality, and double cramped upon the upper surface with cramps of 2 inches broad,  $\frac{1}{2}$  an inch thick, and 14 inches long, and to be put in hot, and buried in a body of lead: the sacia in like manner, composing the balcony sloor, to be cramped with a double set of cramps sixed in the same manner, the joints thereof to be silled, and very carefully pointed with cement made of equal parts of Barrow lime, and pozzolano or smiths forge scales: the aperture or crown of the arch to be set round with an arched circle of stone of 9 inches thick, and the height of a brick's length.

The top of the balcony rails to be at least 3 feet 6 inches above the sloor, and 3 feet high in the bars, which are to be of 14 inch thick, and 100 in number in the whole circle, and the upper and under circle connecting them to be 3 inches broad and 5 inch thick; this circular railing to be supported by 20 studs leaded into the sacia, and turned with a crutch at the top to take the lower circle of the railing without any other fixing thereto than the weight of the railing.

The lower fell of the lanthorn frame to be fet in putty, made of white lead and oil, the upper fell of ditto to be covered with a kirb of wood bolted down, to be cut to a proper bevil for supporting the stone roof; this kirb to be oak; the chimney to be composed of sive pieces, and to be hooped with two strong hoops round the whole, of 3 inches head and 5 thick.

N. B. It will be necessary to cut a small half circular grove under the facia, to prevent the wet from following the under side to the wall. The door in the balcony from the lanthorn to be of oak.

Designs No. 5. and 7. The former being a plan and upright of one of the window-frames for the lanthorn, and the latter a design for one of the 10 cast iron stanchions that form the windows, and support the roof of the lanthorn, drawn at large.

Upon which I have to remark, that the window-frames are supposed to be made of the best clean dry English oak, put together with white lead and oil, and glazed with the best crown glass, each frame to be fixed in place by 32 strong wood screws, and by two small bolts, that take the cross bars; and that all the iron-work, together with the screws, bolts, &cc. and window-frames, are to be put together with white lead and oil, the whole being first painted twice over when tried together, and afterwards two coats when fixed in place.

Design 6, being a section and elevation of the small light-house.

Whatever has been or shall be observed regarding the great light-house, that will apply to the small one, is to be applied thereto, except what is particularly specified by the design or in writing to be otherwise.

The piles under this light-house are supposed to be of the same dimensions, and in number proportionable to the circumserence of the circle of their respective bases, the stone setting between the piles to be of equal depth and solidity.

It now feems more eligible to make the room above the vault a store-room, and to put the two fire-places into the room above, in order to convert it into a dwelling-room, to be stoothed as the other.

The floors to be twelve-inch beams, and common joists 4 by 5.

The height of the mutules are intended to be 6 inches, and the height of the facia 12 inches at the edge, and to rife  $\frac{1}{2}$  an inch at the lanthorn, to be double cramped, as also the chain course at the air-pipe holes, as in the great light-house.

The number of windows in the small light-house as follows:

The room above the vault N.

The chamber and dwelling-room E. W. N. S. 4 and fole stones, as in the great The pipe-room - - - E. W. N. S. 4 light-house.

Open windows 9

N.B. The windows of the rooms and pipe-room to be of the same dimensions as the great light-house.

Upon

VOL. I.

M m

This

This light-house is proposed to be furnished with bellows of a proportionable size to those of the great light-house; but I apprehend the bellows in both light-houses may be omitted till it be seen whether the fire may not have a sufficient draught in calm weather by setting all the air-pipes open, without working the bellows, for unless they are necessary they may be cumbersome, and may at any time be added.

The fack-hole pipe is represented as broken off at top, not only in this elevation, but in that of the great light-house, the part of the arch wherewith it unites being that supposed to be removed from before the eye, but in reality those pipes are to be made to unite with the proper opening through the arch for the sack to pass through up into the lanthorn.

The balcony rails are, as per design, to be the same height, and the iron of the same thickness, as for the great light-house, but the number of bars to be only 80, the height of the lanthorn in the glass to be the same as the great light-house, and the cast-iron stanchions the same.

Design No. 8. is a plan and section of the fire-cage and hearth, upon which I have to remark, that it seems more eligible that the brick-work that supports it should be taised about a course higher, in order to bring the lower ring of the cage even with the top of the stone basement of the lanthorn; and N. B. the spaces between the eight pillars that support it are to be closed with milled plate iron; thick, one side being made to open with hinges and a latch like a door, in order to clear the grate.

Design No. 9. is the plan of the foundation; to which I shall add, that the kirbs, being 10 by 6, are to be of oak, elm, or beech, but that the internal piles are, as already mentioned, to be varied in number, size, and disposition, according as shall appear upon trial by driving after the ground is opened: the foundation here specified being such as appeared proper upon such trials as were made in presence of the gentlemen of Trinity-House, Deptsord Strond, when I had the honour of attending them there.

Design No. 10. being a plan of the vault or basement story, there is nothing to add but that the dotted lines upon the points E. W. N. and S. shew the places of sour airholes to ventilate and give light into the vault.

N. B. I apprehend it may be more eligible to make the entry-doors to open internally.

Design No. 11. is a plan of the smith's shop; shoor to be slagged with natural-saced Elland-Edge slags, well jointed and laid; the two openings B C having a rebate cut round them, are to be covered with loose lids (with a ring in the middle) made of a double thickness of oak plank of  $1\frac{1}{2}$  inch clinched together; the middle hole, though marked 3 seet, need not be larger than the other, viz. 2 seet 6 inches.

The gibbet E to be of oak, and to have  $\blacksquare$  rope of a proper length, with guide pullies for hoisting facks of coals out of the carts, separate from the rope for hoisting coals to the top of the house, each rope to remain reeved, and ready to be applied to the barrel of the machine as occasion shall require n the machine to be made with an iton wheel and pinion compleat  $\blacksquare$ .

In the store-room stoor the door-way, upon the whole, may, in this as the rest, remain in the place shewn in the plan; the beams to be 14 inches square, the joists 4 by 8, and the joists on each side the door-way to be 6 by 8.

Design No. 12. contains plans of the dwelling-room and chamber-floors, wherein it is to be remarked, that the girders lay alternately cross of each other.

In the dwelling-room is proposed two fire-places, that either may be made use of as the wind blows; the funnels are to be carried up in the walls, and lastly carried to the outside, and to be terminated like a cup by corbelling or oversetting the bricks near the top; those funnels to terminate at or about the height of the middle chamber-stoor.

Before the chimnies are to be two hearth-stones of Elland-Edge natural-faced slags of 2 \frac{1}{2} feet broad at least, and 5 feet long; each fire-place to be furnished with a grate or range feet in stones that will bear the fire; the girders of the dwelling-room sloor to be 13 fet in stones square, and those of the chamber 12 inches square; the joists the same as the store-room.

Design No. 13. is added to shew the relative sizes and disposition of the sloors, and seems to require no surther directions than what is upon the sace of it: the girders of the upper chamber-sloor being 12 inches square, and those of the pipe-room 13 inches the upper chamber-sloor being 12 inches square, and those of the pipe-room 13 inches square; the common joists being 4 by 8, and the door-way joists 6 by 8, like all the other sloors.

The beliews and anvil are not supposed to be surnished by the undertaker.

The iron-work for hanging the doors as follows:

The double doors for carriages to be 9 feet clear width in each of the circular walls, to be hung upon well-made loops and crooks, not less than 8 lb. loop and crook together; the crooks to be leaded into stone inlaid in the wall, and the loops to be fixed to the doors with small screw bolts. These doors to be made with proper bars and sastenings to hold them open and keep them shut. The small doors in the circular wall  $2\frac{1}{2}$  feet clear width, answerable to the platform from house to house, to be hung with loops and and crooks of 5 lb. per loop and crook, and leaded into stone with proportionable latches and bars. The vault doors to be hung upon the same loops and crooks as those specified for the double doors of the out-walls, and fixed in the same manner, with each two bars or bolts of 4 lb. each bar, and a lock to each door. The entry doors to have the same loops and crooks as specified for the small doors in the circular walls, with each a lock, bolt, and latch of proportionable strength. The crane doors and balcony doors to have loops and crooks the same as the out-wall small doors, with each a bolt of proportionable size. The trap doors to the floors to be hung upon good HL hinges of at least 10, or T hinges of 13 inches, with one bolt of proportionable size.

All the doors to be plain batten doors, except the two entry doors, which are supposed to be done with somewhat more neatness; all the out-doors to be of whole deal, and the trap-doors, on account of lightness, not less than 7/8 thick when worked; all the doors and floors to be planed and shot clear of sap, and to be lathed, tongued, or rebated together.

The article of painting was not confidered in the original estimate otherwise than by the general article of contingencies; but it is proposed that all the outside wood and iron work be painted with at least two good coats, which has not been already specified to be done with more; all the sash-frames with white lead and oil, all the iron-work with white lead and oil made of a dark lead colour with lamp black, and the doors, &c. with good red priming.

In respect to the lead covering of the balcony-sloor (which was proposed to be done with lead of about 10 lb. to the soot) in case the joints are well cemented, as has been specified, I am of opinion, on reconsidering this article, that the lead may be omitted; and as the roof of the lanthorn and sloor of the balcony will be greatly annoyed with soot and coal-dust, insomuch that it is probable but very little of good fresh water can be collected, it seems that the lead pipe and cistern may also be omitted, and in lieu thereof that the undertaker surnish each light-house with a good stone trough or cistern, to hold

at least two hogsheads each, properly supported on brick-work, with a cover to each, for depositing such fresh water as shall be brought from the main land; and also to cover the hips of the lanthorn roofs with lead; and as in the above articles of lead-work to be omitted, there will be a deduction of 721. 55. 3d. in the original estimate upon the great light-house, and 541. 35. 11d. upon the smaller one, it may be reasonably expected that those sums, making together 1261. 95. 2d. will fully compensate every article of additional expence which was not fully considered in the first estimate, or has on this revisal been suggested.

I beg leave further to observe to this Honourable Corporation, if they can admit both the light-houses to be somewhat altered from the places marked out in the plan No. 1, that is to go upon the same line about 80 yards more to the N. W. in order to bring the small light-house more out of the way of the seas in time of storms at high water, that it would be a means of preventing unforeseen expences in the protecting the out-works of the small light-house from the effects of such insults; and this appeared to me the more desirable when I was upon the view of the temporary lights (in order to make an estimate thereof) as some derangements had happened to the platform and coal-yard near the small light-house by a storm happening at a great tide.

Austhorpe, May 9, 1770.

J. SMEATON.

The REPORT of JOHN SMEATON, Engineer, concerning the state of the Light-Houses building at the Spurn Point, under direction of the Trinity House, Deptford Strond, London.

THE beginning of December last I was at the Spurn Point, in order to view the state of the works carrying on there by Mr. TAYLOR, and sound that the shell of the lesser light-house was erected, and the lanthorn compleatly framed, and set up and ready for receiving the glass, all the naked sloors in, and the hearth erected ready for receiving the grate; so that, exclusive of the balcony-rails, the glass, and inside sinishing, this light-house may be considered as erected.

The foundation for the circular wall round this house has also been for some time laid, and brought even with the surface of the ground.

The

The great light-house was also then raised five courses of bricks above the second timber floor; both which floors were in place, and the arch of the coal vault compleated, as also the stone stairs up to the smith's room floor.

The height of the greater light-house above it's foundation was then 44 feet 6 inches, and near 40 feet above the ground, which is somewhat irregular.

The bricklayers were then at work, and as it is faid there is seldom any frost at the Spurn Point, it is probable that the brick-work done in winter may become even more solid than what is done in summer. The brick-work of both houses is somewhat rough, but as Mr. Taylor seems very careful to have the courses properly grouted, or run with liquid mortar, I have no doubt of the sirmness of the work, and which, at a very little distance, has all the effect upon the eye that can be expected.

On examining his stores upon the place, I found all the timber stoors prepared, together with a large quantity of boards planed and tried up ready for the stoors, doors, air communications, &c. so that I apprehend, taking the work done and preparations upon the place, as they appeared upon my view the beginning of December last, in part of the whole, that 1000 l. in addition would compleat the two light-houses according to the contract.

Mr. TAYLOR applied to me to have his extras settled, that is, the additional piles in the foundations, and depth of building, occasioned by the foundations being laid lower than the plan, and some other things that will be due to him; but I told him that as there might yet be others before he had done, it might be as well to settle all the extras together; to which he did not object.

Mr. TAYLOR has made a greater progress between the last and the former visitation than in any sormer period, and, if not cramped for men or money, I should expect to see the light-houses compleated for use in the course of the present year.

The variation of the Point is become still more favourable to the present situation of the buildings than in my last representation.

Mr. TAYLOR remarked to me a new fand that the sea appeared to break upon at low water, being due east from the lesser light by the true meridian, and at about a mile's distance; this I remarked to some of the gentlemen of the Trinity House on my return to Hull, on supposition they would more circumstantially inform themselves, and acquaint this Honourable Board therewith.

REPORT upon the Lower Light at the Spurn Point, by John Smeaton, Engineer.

FROM a view of the works at Spurn Point, taken the 25th of April, 1776, it appears to me, that fince my representation, by letter of the 22d of January last, the beach has considerably increased, not only in breadth but in height, and not only in the frontage of the low light-house and low temporary light, but sor half a mile at least coastwise towards the north east.

Since then a cargo of Hazlecliff stone has been deposited at the foot of the low lighthouse, upon the bricks reported to have been there deposited in the said letter, none of which appear to have been stirred from their place; but as the cover of Hazlecliff stone is not fully compleated, I have now ordered a further quantity, in order to compleat the fame. A great part of both bricks and stone are buried in the beach, that a more favourable course of wind and tides have brought before the work as above mentioned; so that, from the above state, it appears, that as things have taken that savourable turn that was wished, and hoped for as very possible, the low light-house and low temporary light are not now in the imminent danger that they appeared in in January last; and as there is now a greater appearance of probability that the lower light-house may become and continue serviceable for some years to come, I am of opinion, that the best way to turn the work out of hand, and to give it the best chance of continuance, will be to rebuild that part of the circular wall that the sea has taken down, and, to give it a greater depth and dimensions than before, to make good the ground taken away in the court-yard; that will then again be inclosed solid with Hazlediff stone, and also to deposit a quantity of Hazlecliff stone round the circumference of the new wall outside, in the same manner as is now done round the foot of the building; and lastly to construct fome grynes of fascinery, or stake and rice work, upon the beach, on both sides the building, in order to catch and detain the beach, in a manner something like what is practifed upon the coast of Suffex, in the frontage of Romney Marfb, &c. This is what, from circumstances turning out favourable for the present, appears to me to be now adviseable. Yet the opinion will remain valid that is particularly expressed in the 7th, 8th, 9th and 11th paragraphs of the said letter of the 22d of January, and confirmed by the sketch of the gradual changes made in the Spurn Point since and including the year 1766, remitted in my letter of the 24th of January, viz. that the whole coast for feveral miles being in a confiderable state of waste to seaward, the sandy beach composing the Spurn Point must follow it, and consequently the ground being taken away behind the light-house, it will be left an island, and therefore indefensible, but at much greater expence than that of building a new house, even of the same construction: but that, considering the fluctuating state of the coast to seaward, that it seems more adviseable to exhibit the lower light, whenever the present one shall fail, by means of a machine light-house, built upon the same principle as the present temporary high light. and that by way of provision for the constant exhibition of the lights, for the benefit and fafety of navigation; that, in the mean time, the present large temporary light machine (as foon as those lights are ordered to be struck) be removed into the line as near the low light-house as shall appear convenient. This is the general sense and meaning of the paragraphs in the letter above referred to, and which still appear to me equally necessary now as then appeared; but I now beg leave to add, that if the Honourable Board of Trinity House, Deptford Strond, shall think proper to order the rebuilding the circular wall, and the defences or out-works above mentioned, that it will then be impossible for the sea to render the light-house unserviceable so suddenly as not to give time to do some business. If it should be liked better, the large temporary lightmachine may be taken down, repaired, marked ready for putting up again, and fafely deposited under cover, ready to put up, whenever, by the sea's destroying the outworks, it shall appear adviseable and necessary; but yet, as the timber and iron-work thereof have already been exposed for several years to the weather, it is my opinion that they will last as long, when exposed in the same manner, as if put under cover.

Austhorpe, 30th April, 1776.

J. SMEATON.

ESTIMATE

ESTIMATE for rebuilding the part of the wall of the low light at Spurn Point, that was taken away by the sea, and defending the same, as per Report.

		£.	J.	d.
To thirteen rods of brickwork, at 10%		130	0	0
To timber and piling under the foundations,	-	35	0	0
To Hazlecliff stone, inside the wall and out, 360 tons, at 6 s. 8 d	-	[20	-	
To clearing foundations,	-	5	0	- 5
To gryne-work of fascinery,		10	0	0
Neat estimate,	-	300	0	0
To 10 per cent. contingencies upon the whole,	-	30	0	0
	£	. 330	0	0

ESTIMATE for taking down, moving, and re-erecting the great temporary light, and placing the same in line of the other two light-houses.

											L.	£,	đ,
To taking down,	-	-		-	-		à		-	-	S	0	Q
Removing,		-		~		~		-			, 5	0	0
Repairs that may be wanted, -	-		-		1.00		-		^	-	15	0	0
New foundation, fo as m be moveable,				-				~		*	25	0	0
Re-erecting the fame,	-		**		-		•		•	-	10	0	0
		estima			-		-		100	-	60		0
	To 10	o per i	cent.	conti	ngen	cies				•	- (		0
											£. 66		0
Austhorpe, 30th April, 1776	5.									J.	Ѕме	ATO	N.
ESTIMATE of what I houses at Spurn Point.	have	furt	ther	ord	ered	as	necei	ffar	y to	comp	leat (	he I	ight-

A copper funnel for the great light-house, to be fixed in the same manner as that of the low		L.	24	d.
light, and of a proportionable fize; this, after deducting the value of the present funnel, to be returned,		18	0	0
To fixing, screws, bolts, &c.		\$	io.	Ö
New cast-iron sire-hearths, possibly may come to about - Some partitioning in the small light-house pipe-room, in order to make it convenient to lodge in; an addition to the ash-pipe; and several small jobs that I saw necessary, and			ro	0
ordered when I was there last, about	-	-		
	£	35	0	-
Authorea and January, 1777.	. SM	EAT	ON.	

Austborpe, 22d January, 1777.

The.

The conclusive REPORT of John Smeaton, Engineer, concerning the Spurn Light-houses.

IN consequence of Mr. TAYLOR's letter of the 30th of March last, acquainting me that every thing I had ordered, as well extra as contract work, was done, I visited the light-houses, at Spurn Point, upon the 7th of April, and finding that the capping of the detached circular wall of the lower light was compleated, which for some months past had been the only thing wanted to the completion of his contract works, I gave him a certificate accordingly, of which I advised the Board by letter of the 20th of April; and also therein mentioned, that having staid the night of the 7th upon the Spurn, that the large copper funnel then fixed upon the great light-house compleatly answered the end, as the lesser one fixed upon the low light had done before, so that both lanthorns would go through the whole night, without any necessity for cleaning during the night; and that both lights appear exceedingly brilliant, and the heat within the lanthorns is proportionably less. These are, in fact, very great and essential improvements, both in regard to the light itself, and the advantage of keeping them, and therefore directly tending to keep the expence of maintenance as low as is confiftent with the goodness of the light necessary to be exhibited, and which, as these lighthouses differ materially in construction from any before erected, are matters that could only be adjusted by trial and experience, but which being once brought to bear, will be a model or example for the erection of others. On examination, I found that the grates I had ordered for the new hearths, being as much too small and narrow as the original ones were-too large and wide, the light-keeper (being by trade a smith) had made one for the great light a medium between the two, which had answered, not only for the Stone coal, but for burning a mixture with the Sunderland coals, which, as the Board did not approve the disposal thereof was become the more necessary; but the less lights grate being too narrow to burn the Sunderland coal, I thought proper to order another grate also for the lesser light, by means whereof they said they could burn one third of Sunderland with two thirds of Stone coals; and, according to this rate of consumption, they had as many of the Stone coals as would last till Midsimmer, (of which I took care to apprize Mr. Corthine, the agent,) and as many Sunderland coals as would last several years. Indeed the Sunderland coals are much in the way, as, by occupying the coal vaults, the Stone coals have been obliged to be lodged in the yards, and receive much damage by being exposed to the rains and the frosts.

Lobserved that a good deal of graveh and beach had been laid on before shortester light, and that no material variation had happened in the Point; in short, that things appeared

appeared in as tenable fituation in every respect, as they had done twelve months before, when I advised the rebuilding the wall; and though, according to the accounts I have fince received from Mr. TAYLOR, more beach is still laid on, and matters appear still more promising, yet, as in the great storm at N. E. that happened in February last, the whole of the Hazlecliff rubble was dispersed from the S. E. side of the wall for 60 feet running; and though much pains and care appear to have been taken by Mr. TAYLOR in collecting and replacing the same from time to time, yet the total stock laid outside the wall has been upon the whole considerably diminished; and as storms of this kind must be expected every winter, and there does not appear to me, though a tentporary defence, any thing more likely to be effectual, or to afford a better chance of faving the building for a term of years, without going into expences that cannot with any propriety be supported, as being greater than the expence of the building itself; I would therefore by all means recommend that for the present year 150 tons of Hazlecliff stone be got to the place ready to be applied as heretofore, that is, as it may be wanted; and as I have no doubt but that Mr. TAYLOR, while he remains an inhabitant of the Spurn Point, will not be wanting in his best endeavours to apply these stones to the best advantage for the defence of the buildings, I would advise the application thereof to be put under his management until Mr. CORTHINE can fall upon some more eligible perfon. Yet I must do Mr. TAYLOR the justice to say, that exclusive of such delay and disappointment as has arisen from other persons, that in his own person I think him strictly honest and industrious; and I apprehend it is very possible that after they have got into a way of using the stones in a lesser body, and occasionally as they are wanted, that 100 tons annually may suffice, I mean till an extraordinary revolution happens, for in that case I don't apprehend that 1000 tons would be effectual.

I have already acquainted the board that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls, and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

J. SMEATON.

Austborpe, June 23, 1777.

P. S. The running out and shaping of the point itself was, when I was there last, much in the same state as it was in the year 1774.

The Report of John Smeaton, Engineer, upon the state and condition of the low light-house at Spurn Point, pointing out the most likely means of preserving the same at a moderate expence.

IN the year 1766, I attended a deputation of gentlemen of the Trinity-Houses of Deptford Strond and of Hull, who were also attended by Capt. MITCHELL, who was supposed to know the coast the best of any body: he had peeviously set up marks for the placing of the light houses, according to his own opinion; the line of direction was the same in which they now stand as to the points of the compass, but was more inland, that is, further from the Point than the line upon which the present buildings stand, It was then observed by the gentlemen, that the removal of the present light-house was on account of its being too far from the Point; and as the Point appeared to be increasing, and going out further and further yearly, that the new light-houses might not foon become again necessary to be removed and rebuilt, it was desirable to have them as near the Point as possible, as the probability was, that they would by the increase of the Point leave the houses more and more within the land. The only difficulty then feemed to be, whether the buildings could be so sounded as to stand upright upon this great bed of fand, if built so much nearer the high water mark, upon which I said I could undertake to make foundations upon any part of the bed of fand, fo as to enable the buildings to stand upright upon their bases, provided they were out of the way of the immediate stroke of the sea; and as it was universally allowed by all present that the land was increasing there in every direction, there could be little danger of a direct attack of the sea upon either building, and therefore the gentlemen ordered marks to be put down in the line on which they now stand, at the distance of 300 yards from each other, and which line was then only 115 yards distant from the extreme point at high water mark.

It was not till the year 1771 that the buildings were begun to be erected, when on revisiting the Point I found that it had so much increased in length that it projected at high water mark 280 yards surther out than it did in the year 1766. The land had also increased on the side next the Humber, but had shewn a very apparent diminution to seaward. It had been determined to begin with the small light-house sirst, which being a less ponderous building, if any difficulty should arise in making a soundation, it might be a sorewarning, and thereby surnish the means of conquering the difficulties that might attend the larger and more ponderous building.

Under these circumstances of the Point's having lengthened 280 yards in five years, it did not seem at all prudent to carry the line of the building surther from the Point than had been directed, nor, on account of the diminution to feaward, to carry it further out; but finding room on the fide next the Humber, I advised that they should be carried 80 yards further towards the Humber, upon the same line, than originally they had been proposed, and accordingly the foundation of the smaller light-house in question was laid 80 yards more inland than originally marked out, being there no less than 90 vards within land from high water mark, which seemed to be a very ample allowance for the incroachment of the sea, that hitherto was not supposed to be any other than casual, and that therefore in all probability would increase again on that side as well as the rest: I also on this account ordered the foundation of the building to be furnished with a greater number of piles than originally intended. Having never been at the Spurn otherwise than by water, previous to the laying the foundation of the lesser lighthouse, it was not till that building was considerably advanced that I had an opportunity of remarking the progressive effect of the sea upon the coast, which my frequent journies by land during the progress of the work gave me an opportunity of seeing. In the year 1772 the great light-house was sounded, and though there appeared no diminution of the land on that fide, yet by way of precaution I advised it to be fet only 60 yards from its first intended position towards the Humber, instead of 80, which kept it 20 yards further from the Humber than according to the former position, and also by way of further security, I ordered this foundation to have an additional number of piles in like manner as the former. During the carrying on of these buildings, I not only remarked that the sea was making gradual approaches toward the lesser light-house, but was wearing away the folid land of the coast for many miles to the north of the Spurn: however, its progress was not such as to denote any immediate destruction, till a great storm happening in January, 1776, that in two tides made such an increachment upon the land as to take away the ground from under a part of the foundation of the circular wall, which occasioned one half of it to be beat down, and washed away the ground so as to lay bare a part of the piling upon which the main building stood; and had it not been for the precaution of the additional number of piles in its first founding, it most certainly had given way; however, there did not happen the least shrink.

On this alarming occasion, I defended the building with all the expedition that could be used by a large quantity of Hazlecliff rubble stone, forming a slope against the side of be used by a large quantity of Hazlecliff rubble stone, forming a slope against the side of be used by a large quantity of Hazlecliff rubble stone, forming a slope against the side of be used by a large quantity of Hazlecliff rubble stone, forming a slope against the side of be used to see a permanent defence of the spring the sea rather retreated than surther wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground. Seeing therefore, from the gradual wasting of the whole coast, that wasted the ground about it, and as this could not be island, after the sea had taken the land away round about it, and as this could not be

done but at the expence of some thousand pounds, a much greater expence than what would erect a new building, I therefore advised, as the cheapest defence that could be made, so as to give it the best chance for a time, to rebuild the circular wall, sounding it as deep as we were able at a moderate expence, and fetting it upon piles, and furrounding the wall also with a slope of Hazlecliff stone, and, as a dernier resort, to erect the large temporary light machine in the line of the two buildings, 30 yards from the center of the smaller light-house more inland, and to repair and fit up the same ready for lighting, at two hours warning, so that in case any sudden or violent storm should render the house unfit for service, recourse could immediately be had to the machine light to comtinue the duty, all which was executed in the course of the following summer.

The beginning of the year 1777 there happened another violent storm at N. E. which the work sustained without any other derangement than that a part of the Hazlecliff stones laid on the outside of the wall was dispersed; therefore, after seeing the effects of this storm. I left it as my last advice, that " as storms of this kind must be expected every winter, there did not appear to me (though a temporary defence) any thing more likely to be effectual, or to afford a better chance of faving the building for a term of years, (without going into expences that cannot with any degree of propriety be supported, as being greater than the expences of the building itself,) than a proper application of Hazlecliff stones; I therefore recommended that for the present year (1777) 150 tons of Hazlecliff stones be got to the place ready to be applied as heretofore, that is, as it may be wanted, apprehending it is very possible that after they have got into the way of using the stones in a less body, and occasionally as they are wanted, that 100 tons annually might suffice, that is, till an extraordinary revolution happens, for in that case I don't apprehend that 1000 tons would be effectual,"

· At the same time I observed, that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to the navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

Austhorpe, 27th June, 1778.

J. SMEATON.

The REPORT of JOHN SMEATON, Engineer, concerning the lituation of the Mills and Bleach Field at Waltham Abbey in respect of water.

THE bleach field is at present supplied with water, without diverting any water from the mills, as follows; the ditches are filled by the water from the barge river, which in time of flushes rises high enough to fill them, which slushes are constantly twice a week in the drieft feasons; the water for washing is the water that continually makes its way down the barge river, and in the drieft seasons, when the mills keep the water below the top of Sir WILLIAM WAKE's turnpike, the leakage thereof is found fufficient for the purpose, as I am informed.

When the navigation is diverted from its present course, and this turnpike rebuilt, or fomething in lieu thereof, to hold up the head of water for the mills, it is apprehended that the turnpike may then be made so water-tight, and the leakage thereof so small as not to change the water of the present barge-river with sufficient speed, to answer the purpose of washing the linens; nor can the ditches be then supplied with water as they now are for want of the flushes.

But the ditches may be supplied with water by bore running continually out of the Waltham Abbey mill-pond, and the washing may be supplied by bore running continually (or in the day-time) from the new-constructed turnpike or flood-gate; this will, however, so far as it goes, be a subtraction from the mill's water, but yet may be done so as not to affect the powder-mills at all, and the Abbey mills very inconsiderably; on the other hand, it will be proved that both will be great gainers in point of water by the alteration.

Having, with the assistance of Mr. YEOMAN, Engineer, carefully viewed, measured, and calculated the quantity of water discharged at Sir WILLIAM WAKE's turnpike in the drieft seasons for passing the barges, it appears to amount to considerably more than 14 \* millions of cubic feet of water weekly, which, reduced to an average of the whole week, will amount to 1429 1 cubic feet per minute, flowing continually, and which would supply a bore or round hole in a plank of 23 1 inches diameter, whole center is 2 feet below the surface of the water in the head from whence it is supplied; this is certainly a very great loss of water to the mills, and which must continue so long as the navigation remains in its present state, the greatest † part whereof will be faved to the mills jointly by the alteration.

<sup>•</sup> The number comes out 14,408,875 cube feet per week. The quantity expended by the new navigation will not be above 18 part of the prefent to do the buliness.

Let us now examine what will answer the purposes of the bleach-field: having computed the quantities of water taken in for the supply of the ditches weekly, according to the information of the owner, I find it amounts to 140000 cube feet, that is at the rate of 14 cube feet per minute nearly, which will be supplied by a hole of  $2\frac{\pi}{4}$  inches diameter, running constantly, made in a brass or copper plate of  $\frac{\pi}{8}$  of an inch thick, and whose center is placed 1 soot below the surface of Waltham Abbey mill-pond.

The supply of water for washing, supposing it done in the open river, as at present, would be considerable; but as the width of the stream, when barges cease to pass that way, may, without detriment to the discharge of the flood water, be contracted at low water from 36 to 9 feet before the washing-stages, it will follow, that \(\frac{1}{4}\) of the supply will produce the same velocity of the water in the river as at present, and consequently \(\frac{1}{4}\) part of the leakage may supply it; but as the leakage of the new slood-gates may not be an 100th part of that at present, and greater or less according to the different states of repair they may be in, we will calculate what opening will supply, supposing no leakage at all.

The quantity necessary, when contracted as above, appears to be 135 cubic feet per minute, which will be discharged by a hole in a brass or copper plate of 7 inches diameter, the center being placed at 2 feet below the surface of a sull head.

This quantity, with the former for the ditches, makes 149 cube feet per minute; but the quantity expended at the turnpike by the flushes being 1429 ½ per minute, the quantity requisite for the bleach-field will be only betwixt ½ and ½ part of the water expended at the turnpike for navigation. Hence it appears, that upon the whole, at least eight parts in nine of the present water lost to the mill by the navigation will be saved, and yet the bleach-field amply served: hence, though the whole object of loss is trisling in proportion to the gain, yet there appears a method by which the waters gained may be minutely and justly divided; for if an additional bore be allowed the powder-mills, equivalent to the 7 inch bore at the turnpike, each property then will be equally benefited; for as the water of the bore taken from Waltham Abbey mill head would otherwise be drawn at the mill, there ought to be no equivalent to the powder-mills on that account.

The account therefore will stand thus: To avoid fractions, I will suppose \frac{1}{2} part of the savings to go to the bleach-sield, which being wholly deducted from Waltham mill, a  $4\frac{1}{3}$  part will go to the powder-mill as its sull due, and a  $3\frac{1}{2}$  part to Waltham mill.

The Waltham miller on this occasion, as usual, may not think he has his due, because he will not get in the very same proportion as his neighbour; but let us examine what he will get, and then his right to complain will be better judged of.

When I measured the mill's draught of water on Wednesday the 13th instant, I sound the mill expending at the rate of 1087 cube seet of water per minute, and, as the miller said, was capable with that water of grinding and finishing about 4 bushels of wheat per hour; and he surther said, that in short water times he frequently had not the average of that water to go constant for the whole 24 hours; the quantity saved will therefore be as sollows:

The average of water expended by the navigation per minute being 1429 3	
cube feet, and the half of this being supposed due to Sir WILLIAM WAKE,	Ft.
will be	7143
	149
	5653
Saved to the miller by the alteration, besides supplying the bleach-sield,	2014

Which appears to be more than  $\frac{1}{2}$  of the water that he is in dry feasons possessed of, and sufficient to make an addition to his grinding of 2 bushels an hour constantly; so that instead of being injured, he will be greatly benefited.

But as some water will always leak at the turnpike, and as it is probable springs arise in the channel of the river, I apprehend a bore of 6 inches, at 2 seet under the top of the turnpike, will be a sufficient supply for the washing, and the equivalent will be most properly adjusted either by applying new opening, or by widening the present one at the lowest orisice belonging to the powder mills. The size or widening of the present opening, if that method of adjustment is approved of, I shall be ready to compute.

London, May 16, 1767.

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J. SMEATON.

N. B. The computation of 135 cube feet for the bleach-field washing, is computed upon a supposition of the waters moving 10 feet per minute in a channel of 9 feet wide, and at an average of 18 inches deep.

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REPORT on Waltham Abbey Powder Mills, respecting navigation on the river Lea.

WE, whose names are underwritten, having, the 27th of February, 1771, inspected the powder-mills of Waltham Abbey, belonging to Bouchier Walton, Esq; as also the several works of navigation from Rammy Mead lock to King's Weir, upon the river Lea, in order to examine how far the said mills are, or may be, affected by the said navigation works, are of opinion as follows.

1st. That the said mills are considerably affected in their going when the water is held up by the new stop, called Waltham stop, so as to make more than 3 feet, which is esteemed navigable water, upon the threshold of the lower gates of Waltham lock.

2d. That the said mills are affected, though in a less degree, even when there is 3: feet, and not more, of water over the lower gate threshold of Waltham lock.

3d. We also observe, that the said mills are affected by the water-course leading from the said mills to the river, being not sufficiently clear of gravel, weeds, &c.

4th. It appears that the said mills become also affected by the passages for the water at Mr. WALTON'S weir, called the corning-engine weir, not being sussiciently ample, in consequence of the circumstance above mentioned.

Upon the foregoing matters we propose and recommend as follows.

Ist. That a stone should be firmly put down in a conspicuous place near Waltham stop, to mark the height of 3 feet water upon the threshold of the lower gates of Waltham lock, and that the keeper of the stop should have strict orders from the Commissioners of the navigation at all times to draw the gates of that stop, so far as to prevent the water rising there at any times above the said mark, unless requested for the sake of navigation to the said mills, or the town of Waltham Abbey, and unless intime of sloods, when all the gates being drawn will not prevent it.

2d. After Mr. Walton has cleared the obstructions in the water-courses leading from his mills to the river, that what obstruction to the going of the mill still remainsbe relieved by enlarging the water-way at the corning-engine weir, which we are of opinion will be done by an additional conduit or passage of 10 seet wide, its floor to

be laid as low as the floor of the faid weir, and to be furnished with a draw-gate or pointing doors to pen the water occasionally, so as to enable the barges to pass to the mills as at present; and as this enlargement can only become necessary by the water being pent at Waltham stop too high for the powder-mills, even at 3 feet above the lower gate sill of the said Waltham lock, we are of opinion that this alteration should be made at the expence of the navigation.

Having also inspected Jones's turnpike, we found it not only out of repair, but materially defective, as the gate could not be shut down within some inches, and thereby a great quantity of water suffered to go down the old barge river, to the detriment of the mills aforesaid, as well as others dependant on the said head of water. Respecting which we are of opinion, that the said turnpike should be kept in good repair, on account of the said mills, and that the particular defect of not shutting down should be remedied as soon as possible.

We are informed, and believe it to be true, that the bargemen going downwards, after having passed the aqueduct lock next King's Weir, and taken the quantity of water necessary for passing them through the same, frequently draw a surther quantity to keep them forward, by which means an unnecessary quantity of water is brought down the canal, whereby the said mills are not only detrimented by the loss of water, but the navigation itself; for besides impairing the banks of the canal, the current that helps barges going down obstructs those going up: it seems therefore necessary that proper orders should be given to the person having the care of the new stop of King's Weir, or otherwise to prevent these abuses.

London, March 27, 1771.

J. SMEATON.

The REPORT of John Smeaton, Engineer, upon the state of the river Lea navigation, so far as the mills abreast of Waltham Abbey canal are affected thereby.

A PRIL 3, 1779, at the desire of Bouchter Walton, Esq; owner of the powder. mills at Waltham Abbey, I viewed the state and condition of the river Lea navigation, from and inclusive of the lock upon the cut next below Waltham Abbey cut or canal, up by the course of the said canal to King's Weir, and sound the same as follows.

All the locks constructed without walled chambers, by which means not only much more water is necessarily expended at each lock for the passage of every vessel, but the passage of the vessels themselves are proportionably retarded by taking more time to fill and empty.

The head gates of all the locks within the above district were so considerably leaky, against which the water ought constantly to lay, except during the time of vessels passing, that I could not estimate the constant leakage at less than one of Mr. Walton's mill streams, which in consequence in all dry seasons is lost amongst the three sets of mills abreast of this cut, viz. Ensield mills, Waltham Abbey powder-mills, and Waltham Abbey corn-mills, and which waste of water also retards the passage of the vessels, and which retardation, as well as waste of water, is also increased in case the tail gates are out of order, as I have reason to suppose they are, the tail gates of the lock near the head of the cut next below Waltham Abbey cut, which was the only lock through which I saw any vessels pass were very much so.

The wastes of water above specified, though very material to the mills, are yet very tristing in proportion to the waste that will be occasioned, in case what I was informed of be really the practice, as I have reason to believe it is, viz. that vessels going down very frequently, if not always, after the lock is emptied, and the vessel is let down to the level of the lower canal, draw the cloughts or slakers of the head gates, and leave them both running a full bore of water, the same as while the lock is silling, invorder to make a current down the cut to ease the horses, and help them forward upon their passage; and leave them running without returning to shut them, so that in fact they run till some other person has occasion to shut them, and during this time, which is indeterminate, a considerable portion of the whole river when water is scarce will pass this way, and be lost to the mills abovementioned; it being a rule that what is lost at one lock, will also be lost to all the rest upon the same canal, or head of water. This is a practice that ought by no means to be suffered, as besides a damage of indeterminate magnitude to the mills,

whatever small benefit it may be to the ease of passage of vessels going down, it will be a greater hindrance to vessels going up; and when it happens, as must frequently be the case, that when any of the reaches of the canal or heads of water are drawn down from above, the vessels going up will be prevented navigat n; through the same, and must wait till those reaches are filled, by letting the water down from above in the canals, or till supplied by the currency of the river Lea in the open river; which hindrances to the navigation itself very greatly surpasses any advantage that can be drawn from the slashing of the vessels downwards.

These evils therefore are worthy of remedy merely for the facility of the navigation itself, but as relating to the mills, which can only have the surplusage, will be very destructive in dry seasons; and, I believe I may take upon me to say, very contrary to the idea wherewith the improvements were first framed before the last Act of Parliament was applied for.

For remedy whereof, as far as regards the first, viz. the wharfing up of the lock chambers, it is very distinct to be done now in a substantial manner with brick, as it will occasion the stoppage of the navigation for the time; but they may be wharfed up with piles, planks, and land ties, keeping the navigation open; and where any of the locks so far fail as to need the water to be taken off, they may be wharfed with brick, as, to be substantial, they should have been done at first.

2d. As the mills are more immediately hurt by the leakages of the lock gates, than the navigation, the mill owners and lessess should have power to repair the leakage of the gates, and charge those repairs to the trustees of the navigation, in case they do not do it on competent notice given by the respective millers.

3d. The practice of flashing I do not see any adequate remedy to prevent, but by having a man or lock-keeper to attend each lock, by which the mills can be affected, with a proper but to skreen him from the weather; and two men will be necessary in case the navigation is unrestrained to all hours of the night; which men, as they become the navigation is unrestrained to all hours of the proper mode and utensils of navinecessary by the misapplication of the bargemen of the proper mode and utensils of navinecessary by the misapplication of the benefit of the navigation, should, as it seems to me, be gation, and being also for the benefit of the navigation, should, as it seems to me, be paid by the navigation, or a tax laid upon the bargemen; but being for the security of paid by the navigation, or a tax laid upon the bargemen; but being for the security of the millers, should be chosen or dismissed by the mill owners or lesses immediately interested. Those men (it being made their duty so to do) will prevent much wear and terested. Those men (it being made their duty so to do) will prevent much wear and sear in the use of the locks, and by attending to keep the respective heads of water constantly

stantly full, with as little waste as possible, will thereby save much more time to the bargemen in the course of a voyage up and down, than they can possibly gain by any misapplication of the water.

I must also observe that the banks in many places are too low and too weak, so that when the water goes over them it cuts them down in gullies, and this will necessarily, during the continuance thereof, occasion an extraordinary waste of water through the whole of such canals.

I also viewed the old turnpike, called Sir William Wake's turnpike, which, before the navigation was altered, was used as a pen of water, by means whereof, and through which the navigation passed, but now is of no other use but to open in time of floods, and to be kept shut at all other times, to pen up water for the service of Waltham Abbey powder-mills, and corn-mill, as heretofore, and which for that reason should be kept free from unnecessary leakage. When I saw it, by temporary repairs, it was sufficiently tight; but as it appeared to me, its main timbers and general state of repair and strength, was so much impaired that I should not be surprised if the first great stood of the Lea should take it away, in which case both the sets of mills at Waltham Abbey would be deprived of their water; it therefore seems, that though it is by law to be repaired at the navigation's expence, yet being no longer necessary thereto, it would be proper for the owners of these mills to take the rebuilding and suture repairs upon themselves upon moderate allowance from the navigation.

Austhorpe, April 17, 1779.

#### To the Trustees of the River Lea.

The REPORT of John Smeaton, Engineer, respecting the alterations made at Sewardston mill, so far as they concern the quantity of water taken from the river Lea, as also the loss sustained by Sewardston mill by an alteration made at Ensield lock in the year 1781.

HAVING received no commission from the Trustees of the river Lea to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a prosessional man, upon the premises.

On Saturday the 26th of October last I carefully viewed and examined the mill of Sewardston, also the present state and condition of the gage sluice called Ensield lock. by which water is taken to Ensield mill.

Respecting Sewardston mill, and hearing what is alledged and agreed on both sides, in point of sact, is, that it has undergone no alteration except that of laying the sloor of the corn-mill conduit lower, and the construction of the water-wheel correspondent thereto; that the sell or threshold over which the water issues, as well as the width of the gate, remains the same; this alteration, therefore, I am of opinion, will have the effect of grinding more corn with the same quantity of water, but not of requiring more water to grind the same quantity of corn, and to the height to which a miller may list his gate or shuttle, I can conceive he can be under no restriction:

The mill being tried in my presence, with a full, head of water, it appeared to dispatch at the rate of upwards of 100 quarters of wheat per week.

I also took an admeasurement of the quantity of water used while working at the rate: abovementioned.

I examined the present state of Ensteld lock, being now restored to its sormer state before the alteration, and to the satisfaction of Mr. Whisler; and comparing this with a model produced by Mr. Whisler, and afterwards authenticated by Mr. Nicholls, model produced by him from measures taken at the time when the water was diverted as carefully made by him from measures taken at the time when the water was diverted into Ensteld cut, in savour of the navigation in a greater proportion than somethy; I say, into Ensteld cut, in savour of the lock as I sound it, it appears to me, that there comparing this model with the state of the lock as I sound it, it appears to me, that there would go into Ensteld cut or mill river at that time considerably more water (over and above

J. SMEATON.

above what ought to have gone through the proper gage) than was taken by Sewardstanding mill to grind above 100 quarters per week, as above specified.

But as at the time of the complaint the waters ran so short that it was impossible to have kept up his mill-head to the height I saw it, and therefore could not have ground the same quantity of corn with the same quantity of water, Mr. Whisler lays his account in his ability of only dispatching 50 quarters per week had the water been undisturbed; but reduced in the manner it appears to have been, he actually dispatched but 20 quarters per week, thereby losing benå side 30 quarters per week of what he might, and would have done, agreeable to what he has stated in his case of the 14th of February last, addressed to the Trustees of the river Lea.

As therefore it does not appear to me that Mr. Whisler has made any alteration that enables him to take more water than he is entitled to; and as there does not appear any thing that shall checque, so as to reduce the quantity of grinding lost per week, but rather that from the above circumstances Mr. Whisler's statement of 30 quarters per week appears probable and well founded, I therefore see nothing that ought to hinder the admission of that quantity lost per week.

The whole length of time stated in Mr. Whisher's case of 12 weeks and 5 days I don't find controverted, which he reduces a fortnight on account of the time the gages were shut down for cleansing the navigation; but as during this time he would have the whole water of the river Lea, he would be enabled to maintain a full head, notwithstanding the driness of the season; and therefore in that fortnight could dispatch above 200 quarters, that is, above 100 quarters more than the ordinary rate for dry season if the water had been divided betwixt Ensield mill and himself, as usual. This 100 quarters will therefore compensate the loss of 30 quarters per week for three weeks and two days, which, applied as a further set off, will reduce the whole time that the loss of grinding continued, to seven weeks and three days.

Respecting the rate at which he charges the loss of grinding, viz. 91. per week upon 30 quarters, that is, at the rate of 6s. per quarter, or of 30s. per load, a price that I apprehend to be very far beyond the ordinary accustomed price of grinding in that district of country.

This is not to be doubted, that about the time of the hindrance mentioned, there never was known in man's memory so great and long-continued a drought, and therefore all mills being short of water, there would be a great want of meal at the London market,

and those who ground their own corn (as it is alledged Mr. Whisler does) and could get it to market, would doubtless get extraordinary profits; but as on this head no evidence was laid before me, and it being a mere matter of traffic no ways determinable by rules of engineery, I must of necessity refer this point entirely to the Trustees, to satisfy themselves by such evidence of the fact at the time, so shall further occur, or be laid before them.

It has been observed to me, that the mouth of the mill-stream of Sewardson mill has been widened, contrary to clause in the Act of Parliament, which allows that every part may be made wide enough for navigation to Sewardson mill, which widening, on the other hand, has been denied as to the mouth; I can therefore only say, it is of little consequence to the navigation of the river if wide enough at the mouth for a barge, and there is no restraint as to the depth. This restriction as to the mouth seems to have been introduced as a security to Ensield mill, that drawing from one common pond above Ensield lock, Sewardson mill should not get more than its share.

Austborpe, November 12, 1782.

J. SMEATON.

To

## To the Trustees of the river Lea.

The REPORT of JOHN SMEATON, Engineer, respecting the loss of grinding sustained at Tottenham mills by the leakage of the lock gates, from the year 1778, till April, 1781.

HAVING received no commission from the Trustees of the river Lea to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a professional man, upon the subject before me.

Being favoured by Mr. WYBURD with the state of his demand upon the Trustees of the river Lea, I find it confifting of various articles; but so far as my judgment may be supposed to be of use upon the same, it must be in those articles containing a charge for loss of grinding at those mills during a term, from the year 1778, to the 2d of April, 1781, occasioned by a needless loss of water, arising from the disrepair of Tottenham lock during that time.

In this account Mr. WYBURD particularly states the loss from the 30th of October, 1780, to the 2d of April, 1781, according to notice given to the Trustees of the loss he then supposed himself to be sustaining, viz. at the rate of 51, 10s. per week.

The whole time intervening being 22 weeks, from this he deducts 7 weeks that he was fully supplied with water, there then remains 15 weeks, wherein water was lost in that period, which, charged as above, amounts to 821. 105.

No evidence was adduced to invalidate Mr. WYBURD's charge respecting the length of time as above; and it was very fatisfactorily proved, that not only during that particular period, but for two years before, the lock-gates and flakers had been exceedingly leaky, and out of repair, and also had been misused, and great quantities of water expended to flash boats over a shoal, that had remained in the tail of the cut ever fince its first being opened, till deepened 20 inches by Mr. GLYNN, in April, 1781.

Mr. WYBURD being defired to exhibit some testimony, whereby it might appear that his charge of 51. 10s. per week was properly founded, Mr. Bass, his present millwright and foreman, alledged, that it was the general opinion of himself and millers, that the leakage of the lock-gates was as much as would drive one pair of stones. In further testimony Mr. WYBURD produced m paper, said to be extracted from his books, at the desire of one of the Commissioners, by which, comparing what the mills had done for 12 weeks after the 20th of June, 1780, with what they did in the same period succeeding the 20th of June, 1781, after the lock had been repaired, he finds they did more by 30 1/2 quarters per week in the latter year than the former, though it must be acknowledged the year 1781 was a dryer year than the year 1780.

He flates,	that	in 12	fummer weeks,	1780,	they ground	1029 qua	rters	
average,	рег	week,			-		-	853
Ditto,		-	-	1781.		1395	-	1167
					Difference	loft is	Q <sup>n</sup>	30 1/2

Upon which (as a fact) Mr. WYBURD reasons thus: if, when we ground 85 quarters per week we lost 30, in grinding double that quantity they must have a double loss, and in a triple quantity a triple loss, and so on till they came to five times as much; so that when their grinding amounts to 5 times 85, or 425 quarters per week, their lois amounts to 5 times 30, or 150 quarters.

The different grindings being therefore averaged thus:

1		85	loft	30
2		170		60
3		255		90
4		340		120
5	times	425		150

divide by 5) 450 (90 quarters per week will therefore be the average loss, amounting to 18 loads, which, at 7s. 3d. per load, amounts to 6l. 10s. 6d. per week.

Now Mr. WYBURD, in reasoning upon the fact above stated, takes it for granted, that because a greater head of water which enables them to grind mere corn, produces also more leakage, he supposes them proportionable, so that when they can grind five times as much corn, there is five times the leakage; but this is a very evident mistake, for if with a 6 feet head, and suitable follow of water, they grind 425 quarters, the leakage through the same apertures, will only increase beyond what it would be at the ordinary summers head of 4 feet 4 inches by ; part of the whole, so that if, upon grinding 85 quarters, they lose 30, upon 425 they will only lose 36, and the average loss will not exceed 33 quarters per week, that is, 6 loads 3 quarters. Mr.

Mr. Wyburd's mode of reasoning upon the subject, he seems himself apprehensive, if pursued to its extremity, was leading him into an incongruity, for, says he, "when we grind 500 quarters per week, we don't mind the loss of water so much," that is, though when grinding 425 they were reckoning themselves to lose, and ought to be paid for 150 quarters, amounting, at the above rate, to 101. 175. 6d. per week; yet, when they could do 75 quarters more, and, according to the same scale, would lose the grinding of  $26\frac{1}{2}$  quarters in addition, their loss would not then be worth minding.

That the loss of 33 quarters per week cannot be far from the truth, will appear by examining such collateral circumstances as have occurred.

According to the testimony of Messis. Berner and Rogers, and also of James French, who assisted them in examining the gates in question, by desire of the Trustees, (which they did the 24th of March, 1781) the whole value of the several openings, according to their estimation, and the water discharged thereby, compared with the quantity requisite to grind a given quantity of corn, (as deduced from an experiment made by myself upon this mill) could not amount to more than one quarter per day; but as the gates were doubtless then as carefully shut-to as the circumstances of their disrepair would admit of, which could not in general be the case when handled by bargemen, nor would they, from the same circumstances of disrepair, always shut alike, I look upon this experiment as made in their extream degree of tightness.

Again, it has been fully ascertained and agreed, that during this state of disrepair of the gates, that the lock would sometimes be 15 minutes in filling, and that it was frequently necessary to draw the head-gates open by the tracking horse, sometimes being done by simply drawing them open, and sometimes by the use of a block; and that at such times, according to the opinion of WILLIAM BANNISTER, who preceded WILLIAM BASS as soreman at these mills, the water of the lock has not levelled by about 4 inches: he speaks of this, however, by estimation of the eye, not having ever assuably measured it.

The tail-gates are also agreed to have been more leaky than the head-gates; had the tail-gates therefore been no more leaky than the head-gates, we may well suppose that 3 inches difference would have been sufficient to have brought as much water through the open slakers of the upper gates, as would have supplied their own leakage.

Now the quantity of water that would be vended by the two upper slakers upon a difference of 3 inches want of level, will be a given quantity, and will be equivalent

to the leakage of the upper gates at these times, and this checked with the quantity of water used for grinding a given quantity of corn, as before-mentioned, will amount to the grinding of  $9\frac{1}{2}$  quarters per day: but as it was not necessary for the gates to have been always drawn open in this way, this appears to me to have been the extreme loss the other way, it is therefore sair to check the result obtained this way with what arises from the experiment of Mell. Berner and Rogers, viz.

Qrs. per day.

When the gates were so leaky not to level within 3 inches, loss

tight as per Mess. Berner and Rogers, to lose but

Sum

Half will be the mean 5 -

So that the average loss thus obtained will be 5 \frac{1}{4} quarters per day, or 36 \frac{3}{4} per week, which call 37.

And again, if we check the average result obtained from Mr. WYBURD's experiment, viz.

Against the average result last collected

Sum 70

Average of the averages 35, that is 7 loads, which at Mr. Wyburd's prices, stated at 75. 3d. per load, is 2l. 105. 9d. per week, and which, in my estimation, will be so near the matter as not materially to injure either

£.2 10s. 9d. per week, then, for 15 weeks is £.38 1s. 3d.

The idea of the millers, that they were losing as much water at the lock as would work a pair of stones, I must in this place observe I can have no reliance upon; had it passed through an orifice in one collected opening they might have had some comparative notion, but when cascaded in many different directions through the crevices of lock-gates the best judge of these matters would be liable to be greatly deceived, and from the magnitude of the appearance, judge it much more than it really was, and in this manner their idea of loss would be magnified from first to last.

Respecting, therefore, the charge of £.200 for two years preceding the 30th of October, 1780, no particular evidence was offered upon it, but the general one, that during all this period the lock-gates and slakers were greatly out of order; yet, since it appears that at three different times they were repaired, it is impossible to judge now what degree that at three different times they were repaired, it is impossible to judge now what degree

party.

of loss Mr. Wyburd might suffer during that period; but if his own comparative idea of the matter be taken, viz. that while he was suffering 51. 10s. per week in the period specified between the 30th of October, 1780, to the 2d of April, 1781, he was suffering at the rate of 1001. per annum for the two preceding years, then the yearly allowance must be reduced in the same proportion as the weekly.

That is as 5l. 10s, is to 2l. 10s, 9d. so is 200l. to 92 5 5 Which, together with what was before ascertained, 38 1 3

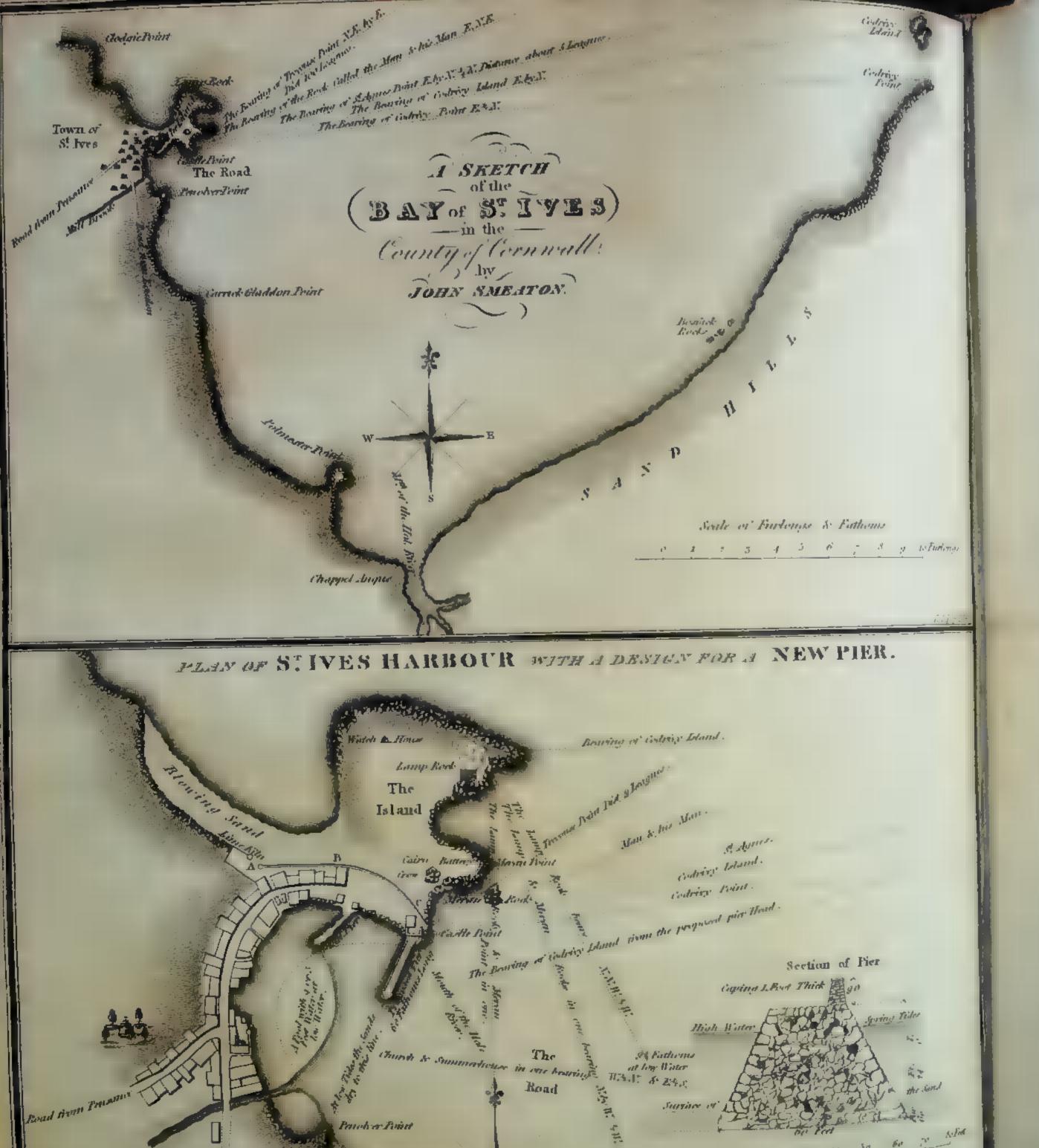
Total for loss of water 130 6 8

With which I am convinced Mr. WYBURD will be fully recompensed for whatever loss he has in reality sustained.

I will only add that I would have it understood, that I have supported Mr. WYBURD'S claim of reparation of injury to an individual as much as I can with justice to the Trustees as a public body; at the same time adverting, that as in the nature of the use thereof lock-gates cannot be made or kept persectly tight for any length of time together, that a reasonable degree of leakage can be claimed by the Trustees as their right, by the same rule as they can take water for the lockage of the vessels, the mill estates upon this river being greatly benefited by the alteration of the mode of navigation from that of wears and stasses to that of eistern-locks.

J. SMEATON.

Austhorpe, November 12, 1782.



Scale of Furlange & Fathonic, Montang. 8 10.

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#### ST. IVE'S HARBOUR.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of making the harbour of St. Ive's safe for ships in all winds.

THE bay of St. Ive's lays about five leagues to the north east of Cape Cornwall, and is the first harbour of any consequence after the entry of the north channel; it lays nearly opposite to Mount's Bay, upon the entry of the British channel; and as there is a great scarcity of harbours on the north side of Cornwall, it becomes of consequence from its situation; not only to ships trading through the north channel, but to such ships as homeward bound from long voyages, by hazy weather, or other accidents which often happen, get into the north channel, when they intended to make the south.

For these purposes the bay of St. Ive's is happily situated, and is sufficiently capacious, it being near four miles in width and above two miles in depth, having in general, and especially near the middle, sull so fathoms at low water, with a clean bottom, being altogether a white sand, composed almost wholly of the small fragments of sea shells, so that having very little of what is gritty in its composition, and the particles being rounded by the motion of the sea, is so soft and smooth as not to hurt the cables of such vessels as anchor therein; and as underneath the sand there appears to be a blue clay (it being frequently brought up upon the slukes of the anchors) is very good holding ground, the anchors being never known to drag when drawing towards the land, as the ground that way gently rises, and in the contrary direction, as the wind blows from the landward, the sea will necessarily be smooth, or if driven out to sea can be of no ill consequence, as the passage is sufficiently open, with sea room enough.

At the north-west corner of the bay a bold rocky promontory, called the *Island*, is joined by a narrow neck to the main land, and projecting confiderably forwards towards the east, forms a natural harbour on the north-west side of the bay, and defended from all winds except the north-easterly.

This interior bay forms the harbour of St. Ive's, and is for the most part lest dry at low spring tides; but on account of the fine soft fand before mentioned, that universally low spring tides; but on account of the fine soft fand before mentioned, that universally lines the bottom of the whole bay, affords a soft easy bed for ships to lay upon when lines the bottom of the whole bay, affords a soft easy bed for ships to lay upon when less that tides; and for such ships as have not occasion, cannot, or chuse not to less that tides; and for such ships as have not occasion, cannot, or chuse not to less the upon ground, here is an excellent road where ships of any burthen may ride, safe from

from all north-westerly, westerly, south-westerly, southerly, and south-easterly winds, in fix and seven fathoms water, at low water spring tides, as appears by inspection of the draught of the harbour accompanying this report, where at fig. 6. vessels may ride in fix fathoms, the point of the island called the lamp rock being open with the Meran point, and bearing N. by the compass, (as all the bearings herein after mentioned were taken) the Meran point distant scarce a quarter of a mile. At 7 there is in like manner seven fathoms, the lamp rock bearing N. by W. and at fig. 9. nine sathoms, the lamp rock bearing N. N. W. 1/2 W. from all which places the church tower bears nearly the same, viz. W. 1/2 N. and at the island of Codrevy E. by N. distant about 31 miles; but vessels are by no means confined to these places, the water growing regularly and uniformly deeper towards the middle, where the general depth is ten fathoms. but these are the marks which ships bring up by, who use the road, in order to be as much sheltered as possible.

From the sketch of the bay it appears, that the rocks mentioned to be without Codrect island, together with St. Agnes and Trevonse Point, stretch north as far as N. E. by E. fo that it appears that the road does not lie quite open except from the north to N. E. by E. these winds are not however dangerous on this coast, as they blow almost right out of the channel; yet it is desirable, for the sake of such vessels as come in here for shelter from the N. W. and westerly winds, or to prevent being driven back to Milford Haven \* when outward bound, or towards the Scilly Islands when homeward bound, and catched with contrary winds; I say for whatever cause it may have been adviseable or necessary to come into this road, it is certainly very defirable that they should have a place of refuge in case they are catched with a hard gale of wind from N. E. while riding there; for to avoid this possibility, many ships are prevented from making use of the shelter the place naturally affords, and by that means meet with an unhappy fate, that might have been very sase in the road at St. Ive's, of which there are many examples.

Conformable to this idea, the island beforementioned stretches away finely to the eastward, and the castle point aims very naturally towards the south, but does not stretch away far enough to the fouth to make a sufficient cover for ships laying aground within the same from the swell that is brought round the points when the wind is at N. E. or N.E. by N. for this purpose it seems requisite that the castle point should be lengthened by art, which, if done in a proper degree, will afford a shelter for above 60 sail of ships from all winds; and to this design occurs the following natural and considerable advantages.

1st. There is a great flow of tide, the spring tides in general rife and fall from 20 to 24 feet; extraordinary great springs flow 26 feet from low water, the smallest at least 18, which least flow, leaving at least 3 feet of water upon the fand at low water at and within the greatest part of the space included between the castle and Penolver. Points, it follows that there will be never less than 21 feet water at spring tides. A neap tide rifes from 14 to 16 feet, and never less than 11, but as there will be at least 7 feet water lest upon the fand at low water, it in like manner follows there will seldom be less than 20 feet water at high water round the pier head, and never less than 18.

2d. It is observed that on the west side of the bay, where the road of St. Ice; is fituated, that for three hours flood from low water, the water runs into the bay in a direction N. by E. and after that, though the water continues rifing three hours more, yet the fet of the current changes to the contrary direction, so that the current fets out of the bay on this fide nine hours, and into it only three; from hence arifes this advantage, that if a vessel is too hard pressed in the road with wind at any point from N. to E. N. E. the can slip her cable, and fail within the pier whenever there is water, as well before as at or after high water; this fet of the tide naturally tending to carry her thither, as also if outward bound she can go out at half slood, and save half her tide up channel.

In short, every circumstance seems to invite the compleating this harbour for the safety of ships where nature has been so bountiful, nor do I see but one untoward circumstance to hinder its perfection, or annoy the same; and that arises from the great quantity of sand, of the species before mentioned, that is brought by the sea into that bay, which is formed by the island on the north side of the town: this sand being thrown up by spring tides becoming dry, and being of a light nature, is blown by the wind over the neck that joins the Peninfula to the main land into the harbour, and comes in such quantities as sometimes almost to bury the houses that stand on that part of the neck. There is no appearance however that this fand increases in the harbour, or stays there beyond a certain degree, which is somewhat variable according to the winds and tides; from hence it is washed into the bay, and from thence part will be carried out to sea again by the reflux of the tides, and part in time croffing the bay by circulation, it is blown and heaped up in immense quantities on the S. E. side of the bay, and in and about the mouth of the Hale river at the bottom of the bay, which is now barred till about half tide, and would entirely be choaked up thereby if not kept open by the great land floods. So that upon the whole there is no appearance of the harbour or road being any otherwife than they now are in many ages, supposing all the solids to continue as they now are; but it may be reasonably expected, on the crection of a pier from the castle point, that a part of the fand that is blown over the neck into the harbour, and from thence Qq

<sup>·</sup> Milford Haven is 32 leagues to N. N. E. and though an excellent natural harbour when in it, yet its entrance is faid to be with difficulty diffinguished in hazy and dark weather. ift. There

now washed away again, may be intercepted by a pier, and there retained; and undoubtedly this in some degree must happen, yet with the precautions that I shall mention, and the provisions that I shall recommend, I am of opinion that the benefit to be expected from a pier ought not to be suspended on account of the inconvenience that may be apprehended from the fands.

In the first place, I would not recommend to carry out the pier further than is necessary to shelter such a number of ships as may probably require to lay in this harbour together; this I apprehend will be done with the length I propose, which is 60 fathoms.

2d. Had it not been on account of the fands, I should not only have proposed to carry the pier out further, but to have turned it more inward like the old pier; but this would in a greater degree have prevented the fands from washing out, nor can it be turned more outwards without laying the harbour too open, and exposing the pier to the direct shock of the seas.

It is probable that, notwithstanding these precautions, the sands will be lodged higher on the inside of the pier than on the outside, as may be seen in the old pier, but yet like those, these will never increase beyond a certain degree, and as there will scarcely ever be less than 20 feet at high water at the pier head, some increase may be admitted without losing the expected benefit: this is exemplified at Scarborough, where a considerable quantity of fand is lodged within the pier, yet the utility of the pier, which has been the work of many years, and many thousand pounds, cannot be denied.

To diminish the quantity of sand that now comes over the neck, in case it is found to annoy the harbour, I would propose to build a wall 25 or 30 feet high, supported by proper buttreffes, in the direction A B C, by which means the current of fand will be directed so as to go over the low part of the island north of the battery on the Castle Point, and be carried into the sea at the little cove between the Castle Point and the battery upon Meran Point, and thereby totally avoid the harbour.

I would also recommend the planting of the sea rushes which are found to entangle the fand, and thereby in great measure prevent its blowing, so that it would be retained in the north bay, where it arises, and increase the breadth of the neck of land that joins the island to the main land.

These things being duly attended to, I am of opinion that the harbour may be kept in a great measure, if not altogether, clear of sand, and if any remains it, may be driven out to sea by constructing a reservoir to take in the tide water, in order to make a scower at low water.

With respect to the construction of the pier, that will in a great measure depend upon the ground whereon it is to be founded; the immediate bottom where the pier is proposed, is entirely sand, such as has been already described, and is to an unknown depth: I endeavoured to perforate the same by a proper instrument, but there being 3 feet water over the fand at low water, though spring tide when I was there, it was impracticable to make so satisfactory a trial as might have been done had the fund been left dry. However, this far appears, that at a little depth under the furface, it lays so close and compact that it was with difficulty that a sharp instrument could be got down 3 feet into the same. It is supposed that at some depth underneath there is rock or clay, and it is probable that the rocks which compose the Castle Point may reach under the sand to a greater extent than they appear above the furface, but it feems very uncertain whether any rock can be met with whereon to found the pier, the whole, or any confiderable part of the length. I therefore in the following estimate suppose that there cannot; and therefore propose to build the pier without any piles or wood-work, upon the principle which the French call Pierre perdue, or cast stones; that is to say, to drop a large quantity of rough stones in a proper direction and width, so as to form an artificial rock or base for the pier; these stones will by degrees link into the sand, and being sollowed by others, these will rest upon the former, and so on till the first or lowest part becomes at rest; for the fand laying very close and compact underneath, will bear any weight when not affected by the action of the fea.

In this method a much greater quantity of stone will be needed than if the pier was built upon a regular hase; but the whole of the base being of rough stones, the more irregular the better, of which great plenty may be got from the neighbouring rocks; as the whole will be done without timber work, and a large quantity of rough stones that would be needed to defend the timber work will be avoided, or rather compose a part of, and be included in the proposed scheme, it will upon the whole not only be much cheaper, but when well settled, more secure than any thing can be made upon a foundation of piles and timber upon the fand.

Upon these principles I propose to raise the pier to half tide, or even to the top, according as the materials are found to turn out; the principal use of this pier being a breakwater, or desence against the sea, the uprightness or lining of the inside for the purposes of a quay are less material; nor is it probable that it can be used for this pur-

Q 9 2

pose, as the spreading of the irregular stones at the bottom will prevent vessels from laying close home to the pier.

Having carefully viewed the feveral places from whence stones are likely to be got, and conferred with Mr. Richardson, mason, who assisted me in this survey, upon the probable expence of winning, moving, and placing the same in order, I have accordingly formed an estimate of the probable expence, as follows.

ESTIMATE for building a Pier in the harbour of St. Ive's of 60 fathoms in length, according to the plan and sketch accompanying the same.

The highest spring tides being 26 feet above the surface of the sand, the pier should be carried up solid at least 30 feet above the same, and supposing the whole to settle into the sand 6 feet, the whole height will be 36 feet, and admitting the sides to batter half the height of the pier on each side, and to be 24 feet broad at top, the base will be 60 feet, and the mean breadth 42 feet, or 14 yards; this multiplied by the height, 12 yards, produces an area or section of 168 yards in each yard running.

It is supposed that a pier built in the manner proposed with a parapet, regularly walled with Aberthaw lime, will be done at the price of 6s. 6d. per cube yard; but as the quantity of settlement into the sand is not quite certain, with other contingencies sufficiently to allow for those, I estimate the whole at 7s. 6d. per cube yard, and this for 168 yards section, come to 63l. per yard running.

	£.	Fe.	d.
To carrying out the pier 120 yards, at 631.	7560	0	Q
The parapet to be 9 feet high, 7 feet base, and 3 feet top, the mean thickness will be 5 feet,			
and contain 5 yards section, which, at 7 s. 6 d. per yard cubic, is 1 l. 17 s. 6 d. per yard			
running, and which for 120 yards is,	225	0	0
To extra work in finishing the pier head, cramps, iron, and lead,	200	0	0
£	C. 7985	-	Q

J. SMEATON.

#### TOPCLIFF MILL.

The REPORT of John Smeaton, Engineer, upon the Practicability of removing Topcliff Mills, Yorkshire, to Assenby Stream, below Top-eliff Bridge, consistent with the proposed navigation of the river Swale.

HAVING viewed the fituation of Affenby stream, as also the present situation of Topcliff mills, I am of opinion as follows:

1st. That exclusive of the dam, which is totally ruined, the mill appears to be in bad repair, and built upon so bad a principle for doing business, as to be incapable of any considerable improvement, without intirely rebuilding.

2d. That the situation of Assemby stream is preserable to the present one, as there may be a better fall.

3d. That supposing the mill and dam to be entirely rebuilt, the only difference, in point of expence, in the present situation, or at Assembly stream, will be in the carriage of the old materials from the old situation to the new one, and in digging the cut at the new situation, and perhaps some additional charge about the mill stable and out parts of the mill-house, which, in its present situation, might possibly be saved.

4th. That the removal of the mill and dam will be equally if not more beneficial to the navigation at Affenby stream, than in its present situation, because it seems to me, that a dam raising the water 7 see, or thereabouts, at Affenby stream, will pen the water up to the same level of the present mill, as it has ever been penned by the dam before it was destroyed; and by building a dam at Affenby stream, the navigation dam before it was destroyed; and by building a dam at Affenby stream in dry seasons.

Northallerton, 14th March, 1767.

J. SMEATON.

#### EYMOUTH HARBOUR.

The REPORT of John Smeaton, Engineer, upon the Harbour of Eymouth.

HE harbour of Eymouth lays at the corner of a bay, at which ships can work in and out at all times of tide, or lay at an anchor fecure from all winds, except the northerly or north-easterly. From this circumstance its situation seems very advantage-. ous; but as the mouth of the river or harbour lies open to the northerly winds, ships cannot lay in safety therein without going up beyond the elbow of the present quay, where the water being shallower by feveral feet, and the breadth much contracted, the harbour is not only defective in point of capacity, but in safety also; for at a full sea the mouth being wide, the fea tumbles in with fo much impetuofity, that great feas find their way round the elbow, and make the vessels even there lay not so quiet as is to be wished; in order therefore not only to enlarge the harbour, but very greatly to increase the safety of vessels laying therein, it is proposed to build a north pier to defend the harbour's mouth, and to this end nature has furnished a ledge of rocks, not only capable of making the most excellent of all foundations for such a pier, but in as advantageous a situation as could be wished, upon which a pier is proposed to be built according to the plans accompanying this report; for, according to the directions therein specified, the harbour will be defended from all such seas as annoy the bay, and the only point from whence the harbour could be affected by seas coming in through the mouth, are land-locked by the points of the bay; so that the harbour will, in its whole extent, be perfectly safe in all winds. It is also to be noted, that the same circumstances that concur to make the harbour safe in all winds, afford the vessels means for getting in and out at all winds \*: and this proceeds from the entry into the harbour laying nearly at a right angle with the di-

being room enough to turn, they can work in till they are near the bottom, and then fail with a fair wind right into the harbour. 2d. If a vessel comes into the bay before the wind with a great sea, she will also have the wind fair to sail into the harbour. 3d. If the wind is right a-head to her going into the harbour, she will have a fair wind into the bay with smooth water, so that after coming to an anchor, she can warp herself into the harbour, and having room in the bay, can work herself out to sea, unless it blows so hard as to bring on a great sea, and if so it would be undesirable to be out at sea upon a lee-shore. 5th. If the wind is right a-head to a vessel desiring to go out of the harbour, as the bay will be smooth, she can warp out, and being out, has a fair wind out of the bay. Lattly, a vessel going before the wind, out of or into the bay, will have a fair wind out of or into the bay respectively; and a vessel going before the wind, out of or into the bay, will have a fair wind out of or into the harbour respectively.

rection

PLAN of EYMOUTH HARBOUR with a Design for the NORTH PIER 33 the main as A denotes the place of the present Bescon. SECTION of NORTH PIER SECTION BLEVATION Fol I Page 3 BLEVATION PLAN for a BRIDGE over STONEHOUSE CREEK PLAN spored extere of the clay Published or the the directs this by Louisson Hovel Rees, Orms and Brown, Fatamaster fore, London,

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rection into and out of the bay; it is also great advantage that here is a good flow of tide, which at spring tides is said to be 20 seet, and there is at the lowest ebb several seet of water at low water between the proposed pier-heads, so that there will be seldom less at neap tides than 16 or 17 seet water in the harbour, which is capable of receiving vessels from 300 to 400 tons, according as they are more stat or more sharp built, and which afterwards can, upon a greater slow of tide, be got into a more advantageous birth.

Another advantage to the executing the proposed design, arises from a great quantity of rough rocks that lay at the north-westerly point of the bay, very proper for building the outsides of the body of the pier, the inside of which may be done with rough stones won or blasted from the neighbouring rocks to that upon which the pier is proposed to be built; by this means the pier may be executed at a trifle of expence, in proportion to the extent and utility of the design; for the rocks that are represented within the intended pier will be removed and made smooth, so as to procure an addition of harbour-room, at little or no charge, as they will be used within the pier: when this is done, there will be an addition of harbour-room in the space between the elbow before-mentioned and the pier-heads, capable of holding 30 ships of middle size, with sufficient passage, and which in time of war will be very useful on this coast, not only for the refuge of coasters from the enemy, but in bad weather for privateers and the smaller sized vessels acting offensively.

What relates to the method of the work itself, will be sufficiently explained by the plans and estimate; I have only to remark, that I do not mean to fix the place of the pier to such precision, as not to be subject to be somewhat varied.

If it is found convenient, on account of fixing the base, to be a little more in, or a little more out, or the head somewhat nearer or surther from the present head, than specified in the plan, I expect the surveyor to use his judgment therein.

Also I don't mean that the ground course of the stones forming the base of the pier should be exactly in a right line, or the bases cut to the same level, or answerable to any given delineation lengthways of the pier; all I desire is, that a bed be cut for each stone declining towards the middle of the pier, as shewn in the plan, but they may be upon different levels, and a little more in or out, as best suits to get a firm sooting upon different levels, and a little more in or out, as best suits to get a firm sooting upon different levels, which stones must be suited in their sizes and thickness for each particular stone, which stones must be suited in their sizes and thickness

In regard to the repairs of the present pier and quay, where it is necessary to begin at the bottom, I advise to drive a row of piles 6 inches in thickness, and close together, edge

edge and edge, and the heads being connected by a string piece, to let the ground course of stones be notched upon them as was done at Coldstream Bridge. The rest of the quay will be defended by laying a tier of rough stones, sloped up against it at the foot. but not so as to be in the bilgeway of the ship.

This would be still more effectually done by driving a row of piles either close toge. ther, or at most but 9 inches distant from one another, and at about a yard distance from the foot of the pier, so as not to be in the way of the vessels, and to lay a slope of rubble stones against the foot of the pier, between the pile heads and the wall, as before described, observing always to slope the rubble down stream. This I think the best way of securing the present quay; but as it will be altogether desended from seaward by the proposed pier, and as the last proposed defence must be attended with some expence and trouble, being only to be done at short intervals of the tide, I advise to cut the matter of repair short by laying stones only, and take a trial of this till the north pier is built.

Austhorpe, May 2, 1767.

J. SMEATON.

1007 10 0

Carried forwards

ESTIMATE for Eymouth Harbour. The expence of building a no	orth pier		
The length within, from the elbow to the faid flank, is 132 feet, which multiplied	cube feet		
by 22 feet high, is 2904 feet superficial, and by 3 mean thickness, gives - 8712			
Total solidity of the first stretch next the head, 35112			
It is faid, that such works as are represented in the inside can be brought from the rocks and laid in place at 6d. per soot, but as I understand this of the loose ricks already quarried, and as the quantity so produced may be short of the whole, and the quarrying is supposed to cost 2d. per soot extra, therefore, to make a sufficient allowance, I make 7d. per soot on the whole: the outside, the workmanship will be more rough, but the stuff being supposed larger, and worse to place and handle, I reckon on that also 7d. per soot.  To 35112 cube seet of stone in the outsides, at 7d.  The whole circumference being 372 seet, this multiplied by 3½ feet mean breadth of the basement course, produces 1302 feet superficial, this quantity of the rock will be required to be cut sloping towards the middle of the pier, and being tide-work, and the rock hard, I allow	£. 1024	1.	d. 0
To 1302 feet superficial of rock cutting for basement, at 8d	43	8	Q
The length of the above being 173 feet, the mean width 24 feet, and mean height feet  22 feet, the whole content, in folid, will be  91344  From which, deducting the outsides, 35112			
Remains for the folidity of the infide filling 56232 which is equal to 2083 cube yards.			

	L.	S.	a.
Brought forwards,	1067	10	0
To 2083 cube yards (after deducting the outside blocks) of filling with rough stones , to be			
placed by hand, and well packed, at 41 per yard,	416	12	0
To 172 feet length of parapet, mean thickness 6 feet, and 9 feet high, produces 344 yards			
folid, which being well walfed and filled with mortar, and built of free-stone rubble,			
allow 7 s. 6 d. per cube yard,	129		
To hammer-jointing and facing both the outsides, containing 3268 seet superficial, at 1 d  The cordon, being 172 seet long, and 2½ seet in breadth, and 1 soot thick, will	1.3	12	4:
contain folid 430			
The capping, being 174 feet long, 3 feet broad, and 1 foot thick, will contain - 522			
The earlings are B. P. L. L. L. B. J. L. L. L. B. J. L.			
Sum 952			
To 952 feet of Leimerton stone, worked, and laid in place, at 11.	47	12	Q
To flooring for the top of the pier, being 172 feet long, and, at an average, 6 feet broad,			
containing 1032 feet superficial of the same stone as the outside of the pier, at 8 d.	34		0
To stone posts for mooring,	\$.	0	0
For 173 feet of pier next to and including the head,	1713	14	4
The length of the pier, from the elbow to Gunsgreen Point, being 181 feet, upon a mean height of 13 feet, the superficies will be 2353 feet on each side; and allowing the mean			
thickness un the outside 4 seet, and the inside $2\frac{1}{2}$ seet, the mean thickness of both sides will			
be 6½ feet, and the whole solid formed thereby 15295 cube feet, at 8d.	446	2	
To 724 feet of cutting the rock for the basement courses, which being less in the tide's way,	312		
I reckon at 6d.	18	2	0
The outside blocks being deducted from the solid contents, there remains for filling 1046 cube			
yards, which being more out of tide's way, I estimate at 3.s.	156	18	0
To free-Rone rubble walling in the parapet, being 8 feet mean base, 21 mean top, and 72			
mean height, contains 264 cube yards, at 71.6d.	99	C	0
To harmer-jointing and facing both the outlides, containing 2896 feet inperficial, at 1 d.	12	1	4
To have work of Leimerton flone in the cordon and parapet, the cordon being 22 feet broad,			
and the parapet the same, and I foot thick; this for 181 feet running contains 905 cube			
	45		5 0
To desire the top of the pier between the parapet and ailler, the mean breadth being 5 reet,	40		
the said and funarhoid at 8 de	30		3 4
To rough flones to be laid in the angle of the pier, adjoining the land at Gungreen I want	810	11	
For 181 feet of pier from the elbow to the point,	1713		
For 173 feet ditto next and including the head,	-7-5		
Sum	2524		1
For contingent expences I generally allow to per cent, upon the whole,	252		7
2 of Contingent expenses 2 5	2776	12	. 8
	in 611		the
N. B. As the rocks within the pier head will be got and made use of	in an	mg	inc
pier, I suppose this to be included in thing of the paint, the expence of	of their	e n	iuit

thought necessary within the pier for vessels to rub against, the expence of these must

\* All stones in the filling are proposed to be put in whole, unless they arise of above two tons.

Rr

STONE-

be added.

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This would be still more effectually done by driving a row of piles either close together, or at most but 9 inches distant from one another, and at about a yard distance from the foot of the pier, so as not to be in the way of the vessels, and to lay a slope of rubble stones against the foot of the pier, between the pile heads and the wall, as before described, observing always to slope the rubble down stream. This I think the best way of securing the present quay; but as it will be altogether defended from seaward by the proposed pier, and as the last proposed defence must be attended with some expence and trouble, being only to be done at short intervals of the tide, I advise to cut the matter of repair short by laying stones only, and take a trial of this till the north pier is built.

Austhorpe, May 2, 1767.

J. SMEATON.

ESTIMATE for Eymouth Harbour. The expence of building a north pier.

ESTIMATION Lymous Transocal	T
The length of the outside, from the elbow and round the head into the stank within, is 240 seet, this multiplied by 22 feet mean height, produces 5280 feet superficial, and this by 5 feet mean thickness, produces solid - 26400. The length within, from the elbow to the said stank, is 132 feet, which multiplied by 22 feet high, is 2904 seet superficial, and by 3 mean thickness, gives - 8712	cube feet.
Total solidity of the first stretch next the head, 35112	
It is faid, that such works as are represented in the inside can be brought from the rocks and laid in place at 6d. per soot, but as I understand this of the loose rocks already quarried, and as the quantity so produced may be short of the whole, and the quarrying is supposed to cost 2d. per soot extra, therefore, to make a sufficient allowance. I make 7d. per soot on the whole: the cutside, the workmanship will be more rough, but the stuff being supposed larger, and worse to place and handle, I reckon on that also 7d. per soot,  To 35112 cube seet of stone in the outsides, at 7d.	f. s. d.
The whole circumference being 372 feet, this multiplied by 3½ feet mean breadth of the base- ment course, produces 1302 feet superficial, this quantity of the rock will be required to be cut sloping towards the middle of the pier, and being tide-work, and the rock hard, I allow	
To 1302 feet superficial of rock cutting for basement, at 8d  The length of the above being 173 feet, the mean width 24 seet, and mean height  22 feet, the whole content, in solid, will be 91344  From which, deducting the outsides, 35112	43 8 0
Remains for the folidity of the infide filling 56232 which is equal to 2083 cube yards.	

	£.	3. 4	de 🗀
Brought forwards,	1067	10	0
To 2083 cube yards (after deducting the outside blocks) of filling with rough stones , to be			
placed by hand, and well packed, at 4s per yard,	416	12	a
To 172 feet length of parapet, mean thickness 6 feet, and 9 feet high, produces 344 yards			
folid, which being well walled and filled with mortar, and built of free-stone rubble, I			
allow 7s. 6d. per cube yard,	129	_	0
To hammer-jointing and facing both the outsides, containing 3268 seet superficial, at 1 d	-		
The cordon, being 172 feet long, and 21 feet in breadth, and 1 foot thick, will	*5	12	4:
my combine being the first burn a few board and a first till 191 . 1			
The capping, being 174 feet long, 3 feet broad, and 1 foot thick, will contain - 522			
Sum 952			
To 952 feet of Leimerton stone, worked, and laid in place, at 1 s	47	12	0
To flooring for the top of the pier, being 172 feet long, and, at an average, 6 feet broad,			
containing 1032 feet superficial of the same stone as the outside of the pier, at 8 d.	34	п	
To stone posts for mooring,	5.		м
		_	-
For 173 feet of pier next to and including the head,	1713	14	4
The length of the pier, from the elbow to Gunsgreen Point, being 181 feet, upon a mean			
height of 13 feet, the superficies will be 2353 feet on each side; and allowing the mean			
thickness in the outside 4 feet, and the inside 21 feet, the mean thickness of both sides will			
be 6½ feet, and the whole solid formed thereby 15295 cube feet, at 8d.	446	2	7
To 724 feet of cutting the rock for the basement courses, which being less in the tide's way,			
I reckon at 6d.	18	2	0
The outfide blocks being deducted from the folid contents, there remains for filling 1046 cube	1 .		
yards, which being more out of tide's way, I estimate at 3s.	156	18	0
To free-stone rubble walling in the parapet, being 8 feet mean base, 22 mean top, and 72			
mean height, contains 264 cube yards, at 7 s. 6 d.	99	0	0
To hammer-jointing and facing both the outsides, containing 2896 feet superficial, at 1 d	12:	1.1	4.
To hammer-jointing and facing both the cordon and parapet, the cordon being 22 feet broad,			
and the parapet the same, and I foot thick; this for 181 feet running contains 905 cube			
	45	5	0
feet, at 1 s.			
To flooring the top of the pier between the parapet and aifler, the mean breadth being 5 feet,	30	3	4
will contain 905 feet superficial, at 8 d.	3	_	1
To rough stones to be laid in the angle of the pier, adjoining the land at Gunsgreen Point,	810	11	
For 181 feet of pier from the elbow to the point,	1713		4
For 173 feet ditto next and including the head,			
Sum	2524		
For contingent expences I generally allow to per cent, upon the whole,	252	8	7
For contingent expenses a Source a	2776	14	8
N. B. As the rocks within the pier head will be got and made use of	in bili	ing	the
N. B. As the rocks within the plant of the pier; but if fender pi	les the	uld	be .

pier, I suppose this to be included in filling of the pier; but if sender piles should be . thought necessary within the pier for vessels to rub against, the expence of these must be added.

\* All stones in the filling are proposed to be put in whole, unless they arise of above two tons. STONE-

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## STONEHOUSE CREEK BRIDGE.

METHOD of construction of the Bridge over Stonehouse Greek, as designed by John Smeaton, Engineer.

O N the Stonehouse side of the bridge there appears, from the borings and soundings made by Mr. John Modge, to be a good hard clay bottom, which gradually declines from the quay towards the middle of the creek, but which at the further side of the channel at low water is 20 seet deep below the mark of low water spring tides; from thence for a space of 250 seet, that is till within about 80 seet of the opposite shore, the clay bottom can no more be felt with founding rods of 26 feet long, which were the length of those made use of, so that for the aforesaid space of 250 feet the depth of the mud is not known; but from the manner in which it declines from each fide, it is not unreasonable to suppose it to lay somewhat like the line dotted out in the plan, but whether this be so or not, the depth of the mud is assuredly so great, that to found the whole upon piles would be so very expensive, as to render the construction in that respect impracticable. It is therefore proposed by removing the water-way about 50 feet nearer the quay than it now is (that is, the middle of the arch to be about 100 feet distant from the quay) to take the advantage of the rife of the clay bottom, in order to found a couple of piers whereon the arch may folely depend, and to make the rest of the passage over the creek by forming a rampart with rubble stone, and quarry rubbish cast upon the surface of the mud, and heaped upon till the stones sirst cast, either ground themselves upon the clay bottom, or by consolidating the mud by mixing therewith, shall make an artificial foundation capable of sustaining the incumbent weight of materials above the surface of the mud; for this purpose, the piers of the arch being built square on the outsides next the ramparts, and quite upright, no fettlement of the rampart will affect the piers, nor will any of the work of the ramparts be displaced in settling by encountering with any projection of the piers, nor will any damage ensue to any part of the work by such settlement, but what may be restored by addition at the top; and as there is plenty of rubble to be obtained on the side next Plymouth Dock, a considerable part of which would have been necessary to have been removed for the sake of forming a proper slope for the road up the hill, it is expected that this rampart may be formed at a moderate expence. The work of the rampart may be begun immediately; I will therefore first describe the manner in which I would propose to carry it on, subject nevertheless to such alterations as difference of circumstances arising from the process of the works shall indicate.

I would propose then to begin at the end where the matter is to arise, bringing forwards the materials in wheelbarrows or carts as shall be found most convenient, merely to tumble them over the creek, observing to reserve the heaviest and best stones for the outside, the second best for the bottom, and the rubbish for the middle: I would advise to carry forward the work to its sull height nearly as it advances, by which means the whole will obtain its sull settlement in the least time. The breadth at top, and slopes therefrom, being as per section, the several widths at the surface of the mud, will be had by consulting the outermost ground lines of the plan; and as the work will begin from the shore, the additional width to begin with, in order to allow for settlement into the mud, will be sound by experience the work goes on.

The section of the rampart shewn in the design being adapted to the line AB, near the middle of the present channel, and supposing it to ground upon the clay bottom there, the beginning ought to be 72 seet wide, as therein shewn.

When the work is advanced some distance from the south-west side, and the mud grows deep, if it is sound to swallow up a greater quantity of matter than is expected; it will be proper, by way of making a kind of bond or platform for the base, to stake down a double thickness of sascines or saggests upon the surface of the mud, and then proceed to throw the stones upon it, as is represented in the section; this will be not only a likely means of keeping the base from spreading as it goes down, but of producing an equilibrium sooner, in case it should not be sound to go to the bottom where the mud is deep.

When the core of matter is found in some measure to come to rest, in order to get the proper breadth at top, it will be necessary to begin at the surface of the mud, and dispose the larger materials by hand, so as to form the slope or batter shewn in the section, which is nearly that of \frac{1}{2} of the perpendicular above the surface of the mud, and is supposed to be the slope of an equilateral triangle below the same.

With respect to the sounding of the pier, as the deeper will be near 10 seet below the low water spring tides, I apprehend it will be quite impracticable to get down to the clay without incasing; I therefore would propose to encompass a square area, capable of just containing the base of each pier, with a single row of dove-tailed piles, of 4 inches of just containing the base of each pier, with a single row of dove-tailed piles, of 4 inches in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found in thickness, the driven a foot or 18 inches into the clay, more or less, as they are found in thickness, the driven a foot or 18 inches into the clay, more or less, as they are found in thickness, the driven a foot or 18 inches into the clay, more or less, as they are found in thickness, the driven a foot or 18 inches into the clay, more or less, as they are found in thickness, the driven a foot or 18 inches into the clay, more or less, as they are found in thickness, as the found in thicknes

shall be found necessary to support the pressure; which lower beams must be made moveable, and taken away as the work advances.

The mud below its surface will render the piles water-tight, and if not found so above, may easily be made tight, by throwing in some baskets of coal ashes, close to the piles on the outside, when the water lays against them.

As I do not expect the bottom to be level, it must be reduced thereto by forming one or more steps, as shall be found most convenient, observing to form the slat of the steps rather inclining towards the hill; and unless the matter happens to be so hard, that the piles cannot be drove therein sull 18 inches, I would have the ground course next the water-way of the arch, and the returns thereof, laid at least 1 foot below the natural bed of clay, that the gulling of the water (which will soon carry away the soft matter down to the clay) may not easily get under the foundations of the piers.

When the first pier is raised sufficiently above low water mark, the piles may be drawn, and made use of in like manner for the other; and if there appears to be the least danger of the gulling of the bottom by the water, I would advise a part of the piles, of which the dam has been formed, to be cut to a proper length, and placed in the groove already formed, so as to be driven down, or cut off below the surface of low water spring tides; this to be done in the face of the piers, next the water-way, and the returns of the angles, but to the remaining parts of the piers it will be useless.

As this business will be tide-work, except at neap tides, it will be necessary to procure one or more good chain pumps, in order that the cavity may be expeditiously cleared of water; it will be adviseable to have a couple of upright square pumps, of about 8 inches, (as they will stand in less room) to keep the water out after the bulk is evacuated, and for the standing of which an upright groove or recess may be formed in the back side of the piers; I advise two, that one may be in order, while the other is cleaning or repairing.

The arch, the facings, cordon, and capings, I would propose to be of Portland stone, the rustic part of the pillars of Moor stone, the body of the parapet over the arch of Plymouth marble, cut aisser, the spandrills of the arch of the same, either coursed or rough, as may be thought most proper, and the body of the piers below the rustic may be aisser'd, either with Plymouth marble or Moor stone, as may be thought proper on account of price; but if no great difference, I would advise Moor stone, as taking more kindly to the mortar, especially where constantly wet. The whole of the inside core I propose

propose to be of rubble from the neighbouring rocks. It will be adviseable to set the whole outside up to high water neap tides with Watchet or Aberthaw lime, and it would, as Plymouth lime is very tender in water, be also very adviseable that a quantity of the aforesaid lime was procured to mix with that of Plymouth for the inside work to high water spring tides: this is the more necessary, as Plymouth lime and marble do not seem disposed to form of themselves very compact body, when constantly subject to the water.

Not having a plan of the quay at Stonehouse and housing adjacent, I have drawn the bridge straight; but as it may probably be found more suitable and convenient to make the rampart somewhat curved from the arch and termination upon the quay, I leave this to the determination of those concerned in the execution upon the place.

The above is, I think, the most material of such directions as at present occur, and which I hope will be found sufficient for beginning; if any thing is not sufficiently explained, shall be ready to do it by letter.

J. SMEATON.

London, June 15, 1767.

# LINTON DAM AND SWALE NAVIGATION.

The REPORT of John Smeaton, Engineer, upon fundry points relative to the Linton Dam and Swale Navigation, referred to his confideration by John Smith, Engineer for the said works; by order of the Commissioners.

#### The points were the following:

1. WHETHER any, and what allowance may be made for the declivity of the rivers Ouse and Swale in dry seasons, so as to depend on making a depth of water beyond the dead level of the height of the dam.

Answer. It is the practice of engineers in levelling to allow one inch per mile for the least sensible current, and this I apprehend may be safely allowed, but not more; I don't mean that there can be no current, under an inch in a mile; but that all methods of levelling are so precarious, where such minute differences are concerned, that it is a safe to make that allowance as to rely upon any other method to prove it, especially as it is easy in practice to remedy the defect by adding a rib of wood to the crown of the dam, in case its height should be found desective by a few inches.

2d. Whether the height of 11 feet above the surface of low water at Linton is necessary for the dam there above that surface, in order to make good the water to the mark near Milby Staith, which, according to his levelling, he makes to be 11 feet above the said low water surface at Linton.

Answer. The difference of 11 feet between the mark at Milby, and the low water at Linton, is precisely the same that I made it; which I particularly remember, having explained it to the committee in London, how I came to expect to raise the water to my proposed height at Milby by a 10 soot dam at Linton, observing that the distance being eight or nine miles, according to the common allowance of an inch per mile, that would make so many inches, and the remainder would be made by the thickness of the sheet of water going over the dam. If still remain of opinion, that, for the same reasons, if the dam at Linton, its crown is raised within one foot of the dead level of the proposed point at Milby, that the water will rise to its mark, at least so as it may be helped by a rib of wood as beforementioned, it being impossible to take levels with absolute certainty for

so great a distance. It is however to be remembered, when my plan was originally projected as above, the Linton dam was supposed one undertaking with the Ure, and being no more than a general design to shew the practicability, the utmost accuracy was not wanted; but as it may prevent any jealousy between the different parties interested if the Linton dam is raised within half a foot of the dead level of the mark at Milby, I think it cannot fail to raise the surface of the water in its driest seasons to its mark at Milby.

3d. Whether the design prepared by Mr. SMITH for the dam at Linton is ■ proper one for the purpose.

Answer. The design exhibited is I apprehend upon the same principles that at Naburne, but with improvements; and as that at Naburne has stood the test for several years, I cannot doubt but this will do the same if executed with the same care and judgment. It would feem to me to be more unexceptionable if the base was enlarged by 6 feet, and the top diminished by 6 feet, the lowest step to be raised 2 feet above low water, and the afcent from thence to the top to be divided into three equal steps instead of two. The greatest objection I have to this construction regards expence. It is greatly different respecting the body of the dam from what I proposed, and with the principles of my proposed construction; but I have acquainted Mr. Smith, where the reputation of an artist is concerned in the success of his works, he certainly ought to proceed upon his own ideas, and not those of another. This is certain, had the navigation been opened before the Linton lock and dam was begun, which was the declared preliminary of my original estimation, in order to bring down stone from above for the construction thereof, that it would have been erected at a much less expence; as it now is, it may be a matter of computation into which my present occasions will not permit me to enter.

4th. Whether the defign for Linton lock is properly adapted.

This lock is I apprehend upon the same construction as I have seen several by Mr. SMITH's father built several years ago, and which have stood and answered very well; the principal articles, in which I differ in grounds where I use wood bottoms, are the following.

Ist. A bearing pile under each fill, ranging in the face of each wall, (but this is rendered less necessary by a sheet of piles, in Mr. Smith's construction, under the face of each wall;) a ditto under each sill answering the middle of the chamber, and if the ground is more soft, a pile under the outward end of each sill.

2d. The

2d. The great fill for the lower gates, the pointings framed therewith under the thresholds, in order the more firmly to be bolted thereto.

3d. A double row of rabbeted piling at the lower gate fill to prevent the passage of the water in case the chamber-stoor should become desective.

4th. The coffin stones made alternately long and short, broad and narrow, in order to prevent their walling joint and joint, as it seems to me must be the case if made of one dimension, as prescribed by Mr. Smith.

5th. In good gravel bottoms, where stone is cheap, I have used it instead of wood, still keeping row of piles under the face of the walls, with a ribband or string piece upon their head, two good rows of rabbeted piling under the lower gate sills, and a row of ditto at the tail of all.

The masonry of the lock in general seems well designed, and substantial; but after all designs, good execution is a great matter.

# KNOUCH BRIDGE MILL.

Proportions and directions for building the Mill at Knouch Bridge, by

JOHN SMEATON, Engineer.

THE two water-wheels for common use to be 11 seet 6 inches diameter, out and out, and 8 seet wide, the shrouds to be 9 inches above the soal, and to have 36 buckets, the rising boards to be  $4\frac{1}{2}$  inches broad, and the breadth of the bucket-board such, that the point of one bucket may advance to the center line of the heel of the next bucket, and the cutting edge to be thrown to the outside.

The bucket-boards should not be of above t inch in thickness, and to strengthen them, I recommend shroud in the middle; the construction I commonly use in wheels of this fort, is three pair of class arms with three rings, and then to put on the boarding of the soal parallel to the axis, so that the boards are nailed down upon the rings ike a stoor upon joists. The wheel case or race to be made to a true sweep, answerable to the wheel, to be continued from the lowest point under the axis for a quarter of a circle, ending at the height of the center, above which the breast wall to be continued upright to a proper height for supporting the trough, which, if thought proper, may be made of stone to the front of this breasting. The water in taking the wheel shoots backwards, so that the wheel turns the same way round, and the water is delivered at the tail, as an under-shot wheel; the water is drawn by two shuttles, answerable to the particular form of the trough, so far as relates to the drawing on of the water, without a drast, this shall be supplied in due time.

The water-wheel being 11 feet 6 inches diameter, there will remain 2 feet to compleat the whole difference of 13 feet 6 inches; the whole height required for the furface of the water above the top of the wheel being only 1 foot 6 inches, there will remain the water above the top of the wheel being only 1 foot 6 inches, there will remain 6 inches either to be added to the head of water, or to admit the bottom of the wheel to be laid 6 inches out of tail water, or to be expended partly one way and partly the other, according to the judgment of the artist.

### Nos. for the two over-shot wheels.

The great-cog wheel	*	${64 \atop 25}$ at $5\frac{1}{2}$ inches pitch
The great lanthorn upon the upright axis	4	253
The spur-wheel upon the upright axis	-	72
The 5 foot greystone lanthorn -	-	19
The 4 foot cullens or blue ft me -	-	at 3½ inches pitch.
The 3 foot 101 French stones -		14
The 3 foot 7 inches cullens or blue stones	3 -	13
The 5 feet greystone for shelling oats, its l	anthorn	1 15 j

N. B. The numbers above being put upon the spindles of each pair of stones respectively, and all being supposed to be placed round the spur-wheel, they would all go at their proper paces if driven together: therefore they may be suited together to either mill, as best suits the convenience of the miller.

For the flood-mill, it being proposed to remove one of the present water-wheels from the Whiston old mill, which are 14 feet 8 inches diameter in the ring, I propose to continue the same number of floats as at present, but to alter the mortices, so that the starts may hold the floats pointing to the center.

The float-boards to be I foot broad, and so as to form a circle of 17 feet 4 inches, the rest of the space to be filled up by oblique breast-boards like the wheels at Kilnburst forge; but shall shew the particular degree of obliquity, by a drast along with the trough for the over-shots.

The width of the wheel may continue the same as at present, viz. 5 seet 2 inches, but if it can conveniently be augmented to 6 seet, it will be the better.

The flood-wheel I propose to be a breast-wheel, and to be laid 7 feet below the full head, viz. the nose of the gate to be when shut 2 feet below head, and 5 feet fall; now as this will make the bottom of the flood-wheel 6 feet or  $6\frac{1}{2}$  feet above the common tail-water, and as this wheel will do business with 3 feet or  $3\frac{1}{2}$  feet tail-water, it follows, that it will do business when this river is from 9 to 10 feet higher than in its ordinary state,

The numbers	proposed	for this	s wheel m	follows :
-------------	----------	----------	-----------	-----------

The great cog wheel		84 cogs at a 5 inch pitch.
The greatest lanthorn on its upright axis	~	25 at a 5 inch pitch.
The spur-wheel on the upright axis		
A pair of 5 feet grey stones	-	at a 31 inch pitch.
A pair of 4 feet cullens	-	15

N. B. If any other forts or fizes are thought proper, the numbers or the spindle lanthorn will answer, if made respectively the same as those for the over-shot wheels.

The over-shot mills above proposed will both be turned at once, with the same quantity of water wherewith one of the wheels of Whiston old mill was worked when I was there, and which was said to be about the whole quantity in dry seasons. This quantity will enable each of the over-shot mills to grind with great ease at the rate of a quarter of wheat per hour, that is 16 Winchester bushels per hour by the two wheels.

The breast-wheel will grind the same quantity as either of the over-shot wheels, but will require a double quantity of water, that is, it will require as much water to grind eight bushels per hour, as both the two over-shot wheels will require when grinding at the rate of eight bushels each; but as the two over-shot wheels will work at the rate abovementioned with the common summer's water, I apprehend it will seldom happen but there will be water to spare, and therefore it may be worth while to consider whether one of the over-shot wheels may not be omitted, and the breast-wheel used in short water times in its stead, and by that means the breast-wheel be brought to act in a double capacity, as a short water wheel as well as solve should be solved.

The over-shot wheels will work with 3 or 4 seet tail water, at which time there will be necessarily such plenty, that it will be very immaterial whether the breast-wheel takes more or less.

London, 15th June, 1767.

J. SMEATON.

P. S. If the staves of the great lanthorns are made of cast iron, as will be advise. able, they may be made of a flattish or oval figure, and thinner than if made of wood, fo as to give room for a stronger cog.

The following sketch respecting the situation will, I hope, make the whole clear,

Vol.J.Page 316 . A Sketch for placing the MILLS EXPLANATION: near AB. The two Overshot Wheels C. The Breast or Flood Wheel. KYOUCH BRIDGE. D. The Mill house for the Overshot Wheel E. The Mill house for the Breast Wheel 3. If either of the Overshot Wheels Aorl should be thought proper to be omitted then the Wheel C. may stand in its place & the Mill house E may be omitted Knouch Bridge Road MILL POND Published as the flat Errett, 200 to Longman Harst, Reas, Orme and Brown Enternessee Rev. London.

#### RIVER COLN.

PLAN for ascertaining the proportional quantities of water slowing down the high stream and Iver stream, being two divisions of the river Coln below Uxbridge, from whence also may be determined the quantity of water discharged at each place per hour.

THE sketch annexed is solely explanatory to save many words in description, and is therefore supposed not to be drawn from a scale.

The point A shews that branch of the river which comes from under the westernmost bridge of Uxbridge; this is not the whole of the river Coln, a considerable stream being diverted therefrom, called the Cowley stream, which crosses the great western road nearer the body of the town.

Below the point A the branch in question divides, one part turning the water-engine or colour-mill, and seems to have been an artificial cut, but the greater part of the water goes down the old river; those streams unite at B, and are again divided at C into two streams, called the high stream and Iver stream, the former being much the largest; from the point of division C the water runs with sentle current to the bridge D, where, meeting the ford where the road crosses, and being somewhat pent up, it runs more rapid from thence to E, where this branch subdivides, but afterwards unite and join with the stream beforementioned.

From the point C the Iver branch runs with a very languid current till it meets the island F, after which it runs more briskly, as also at the bridge and ford at G it runs again languid till it gets into the inclosures, and then more briskly through the inclosures till it gets to the second bridge at H, where there is a further obstruction and fall, and from thence it runs to Iver mill.

Now, if a water-gage is erected upon the high stream, and another on the Iver stream at any place so far below the point of separation at C, that the water running from C to D, and from C to G, shall not be interrupted in its natural course, then those water-gages will respectively shew the proportion of the two streams, and afford a means of computing their real quantities, independent of any enquiries or evidence to be collected from the millers, and which may be executed in the following manner: Upon the branch of the high stream E L, and near the point L, let a water-gage be erected of

N. B. The water-course IR seems intended to discharge the overplus water in times of floods from the Irer fream into the high stream, the mouth of the passage at I being stopped up with piles.

30 feet in width, the fill whereof to lay even with the common surface of the water in dry times, to be terminated by two upright posts, and if need be, one in the middle, so to divide the same into two passages of 15 feet each, the whole to be made close and tight underneath the fill and on each fide the posts, so that no water may pass during the use thereof but through the 30 seet passage over the sill, and consequently will fall over the same like a tumbling-bay. While this is erecting, the water may be turned through the passage EM, which will go to the mills as at present, but when compleated, the water, being stopped from going through EM, will wholly be obliged to pass the water-gage at L, and will raise the water there so little as not to affect the run of the water from C to D. Now, as the Iver stream runs more languid than the high stream, it will be necessary to go somewhat lower down, suppose to the bridge H, a little above which at N let a similar gage be erected, but with this difference, that as the Iver stream is not supposed to be above half the currency of the high stream, a gage of 15 feet will equally carry the water. As this width will not occupy the whole river there, the gage may be erected on one side, while the water let down to the mills on the other side, and being compleated, the bye passage must be stopped up, and the whole of the water be obliged to pass the water-gage, as in the other.

Now, upon turning the water through the two gages, if the depth of the current water upon the fill is equal, then the quantity will be in proportion to the widths; that is, that the currency of the high stream is double the currency of the Iver stream; but as the depths at first trial will probably be found unequal, let as many boards be put into that gage (end-ways up) upon which the water runs shallowest, as by straightening the water-way will cause it to run of equal depths with the other, then will the proportional quantities be as the widths respectively, when so adjusted, and this will be shewn by inspection, according to the various states of the river in dry seasons, whether the mills are drawn or not, and the experiment may be continued (with a proper attendance) for a month, or fuch time as shall be thought necessary; and account being kept of the depth of the water at different times, answerable to given widths, will afford a means of computation of the real quantity in tons per hour; but the computation of the real quantities is more matter of curiofity than use in the present case, for as the proposition is to take away no more water from the confined stream at A, than is due to the Iver fiream, in any one given state, therefore more especially in the lowest state, it will follow, that if the whole river at A was afterwards parted by a gage, similar to those in the experiments, whereof that representing the Iver gage is conveyed to London, and the other to be conveyed down the high stream, after the Iver stream is stopped up by a dam, then will the high stream remain with its present quantity of water as heretofore, nor will it be surcharged in time of floods for want of passage down the Iver branch; because, whenever the river at C rises so high, as to afford more water than

the mills can use, the stop or dam upon the Iver being made in the form of a tumbling-bay, the surcharge will be conveyed down the Iver, and for several months in the year will be a considerable running stream.

It will be necessary also to put a small gauge upon the little brook that falls into the Iver at the bridge C, which, when reduced to the same depth, must be deducted from the width of the gauge at N, and the width so reduced, in comparison with the gauge at L, will give the true proportion of the separation of the waters at C, and of the proposed separation at A. Again, as a quantity of water is proposed to flow down the Iver stream, in order to supply the neighbouring meadows, villages, and the town of Colnbrook with water, whatever the aforesaid little brook shall exceed or fall short of what shall be thought proper for that purpose, a due allowance can be made in the width of the gauge proposed to be erected at A.

It may be objected, that when the water due to the *Iver* stream is deducted from the river at A, that then the engine or colour-mill will lose a proportionable quantity of water; but as the water flowing down the main stream is not employed in working any mill before this reunion, if, in dry seasons, the main river is straightened, in the same proportion by sold flood-gate to be erected at O, and to be drawn up in times of floods, then will the engine or colour-mill be in all respects in the same condition it now is

It may a so be observed, that the obliging the river to pass the water-gauges at A, may, in floody seasons, pen the water upon the tail of the mills just above the bridge of Uxbridge; but as this partition will only be of use in dry seasons, it is proposed that there shall be a set of flood-gates, that being drawn up, shall leave the river as capacious as it is at present, and, consequently, the mills in the same condition; it is also proposed, that the water-gauge at A shall not be erected so as in dry seasons to pen up the water above the bridge of Uxbridge higher than it now is, so that the mills above the same shall not, in any season, be affected by the proposed undertaking. It is supposed, that this method of the partition of the water is (if possible) more unexceptionable posed, that this method of the partition of the river or colour-mill head near A, as formerly proposed; but that if this method be thought more eligible, as the gauges above-merly proposed; but that if this method be thought more eligible, as the gauges above-mentioned will afford a just method of computing the real quantity of water discharged by the Iver stream, a quantity may be taken by the method already exhibited, which shall the Iver stream, a quantity may be taken by the method already exhibited, which shall never

never exceed the just proportion in the drieft seasons, and in all others rather fall short than exceed it, and still the furplusage, when too much for the mills and grounds, be discharged by the Iver stream in the same proportion as heretosore.

Austborpe, July 8, 1767.

J. SMEATON.

#### PORT GLASGOW PUMP.

DESCRIPTION of a Pump for the dock at port Glasgow.

HE water left in the dock at a medium to be evacuated by pump-work, as taken the 22d day of August, 1767, was

> Mean length -  $243^{\circ}$  Solid contents 21141
>
> Mean breadth -  $36^{\circ}$  Cube feet =  $627\frac{1}{2}$  tons.
>
> Mean depth -  $25^{\circ}$ Mean depth

This quantity to be raised in 4 hours to the mean height of 4 feet will require 6 men working at a time, and good English labourers, will continue at the same rate for the whole time; but as the labourers to be employed will probably be such as can be promiscuously picked up, it will be proper to have two sets to relieve each other.

The distance of the chains from the axis of the lever to be ; of the length of the lever; it would be most convenient to have the center of the chains 2 feet from the center of the lever, but should not be less than I soot 6 inches.

The diameter of the working barrels to be 17 inches; and it would be well to have them lined with cylinders of hammered brass or copper, as iron will rust in salt water, and the bare wood will chamber too fast.

In the working of this pump it is to be noted, that when the height of the water without exceeds the height of delivery, that it will never rife higher in the mounting pipes above the chamber than just to force its way outwards, so that the water will never be raised to any height that is unnecessary, and with a proportional addition of force will throw out the water at all times of tide.

The 2 barrels A B are connected together by a square box or trunk CD, into which are 2 square passages through the working barrels EF, about 8 inches high by 10 or 12 inches wide; in the foreside of the box is an hole 10 \frac{1}{2} diameter, so as to receive a pipe of  $8\frac{1}{2}$  or thereabouts, which pipe is to be rammed tight, and to lay through the wall or bank into the open sea, the outward end of which may be guarded by a valve if thought necessary; but if the lower valves of the pump are tight, no water can revert into the dock; it will indeed rife to an equal height in the mounting pipes, but will there be at rest.

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The buckets I would propose to be made in the same way as those for fire-engines, and the lower valves to be made double; I propose them to be framed upon a cast-iron plate, closing up the bottom of the barrel, and which may be screwed to the barrel by 6 or 8 bed-screws, the nuts of which to be let sideways into the wood.

#### HHHH are blocks for the pumps to rest upon

The iron rods and buckets will, I expect, be of weight sufficient to carry them down, but they should be steadied by passing through a plug or collar in the top of the mount. ing pipes.

The valves must be made light, particularly of the buckets, that they may meet with the less check in descending, and the whole leathered with pliable leather, which will be fully sufficient for a column of so small a perpendicular:

If the employment of 12 men for 4 hours be thought too much, this work may be done in 3 hours 20' by 2 ordinary horses, the pumps being contrived upon the same \* principle, and 3 pumps to be worked by a triple crank, the proportions as follow:

Diameter of the working barrels

Length of the stroke - - - 3 feet

No.

L'anthorn on the crank spindles 19 cogs at  $4\frac{1}{2}$  inches pitch

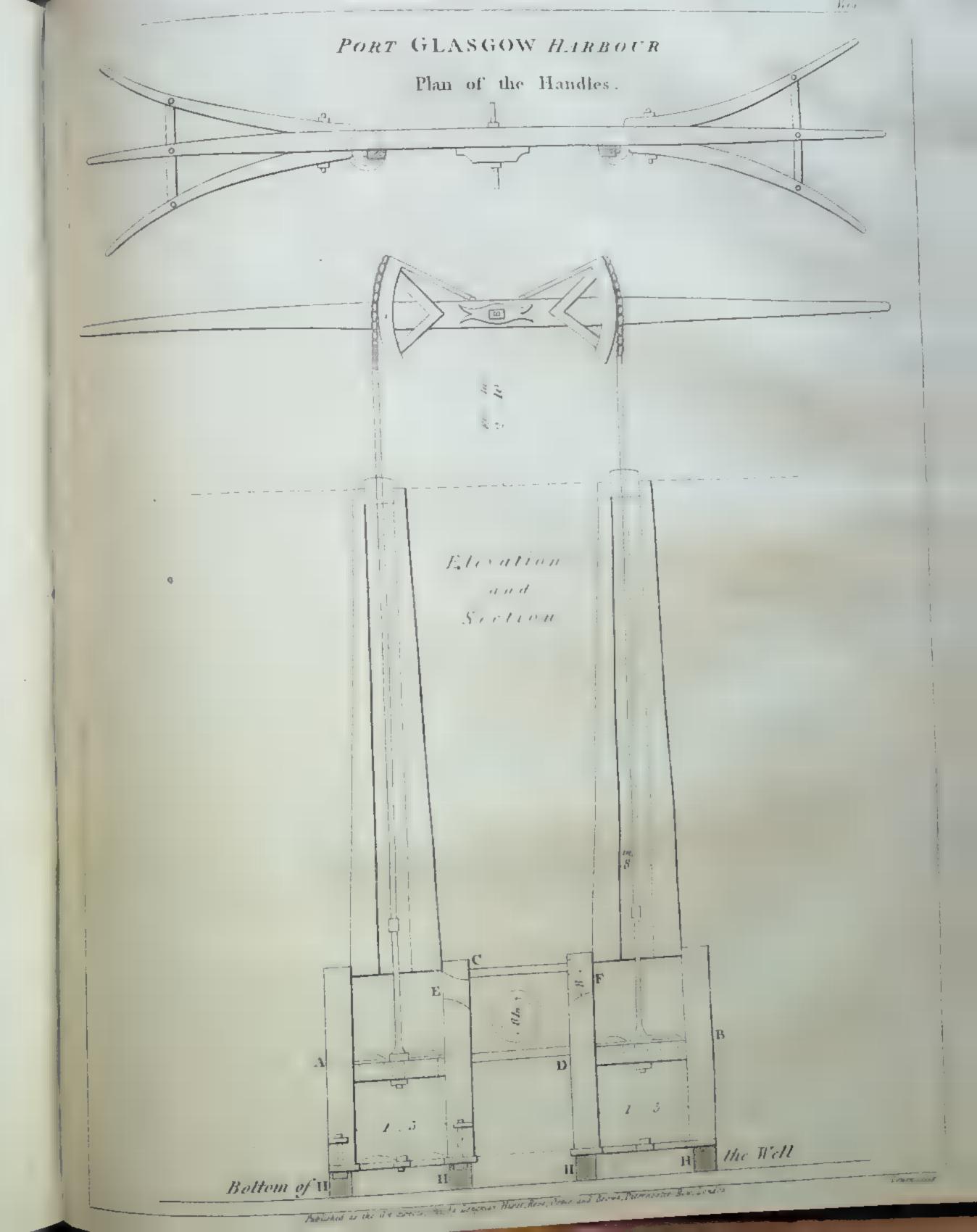
Face wheel for driving ditto 84 cogs at  $4\frac{1}{2}$  inches pitch

Mean diameter of the horse-tract - 21 seet

Austborpe, 4th September, 1767.

J. SMEATON.

That is not to lift the water above four feet at low water, and no higher than to overcome the reliftance. from without, at all other times.



#### RIVER TRENT.

The REPORT of JOHN SMEATON, Engineer, concerning the Water-Road proposed to be carried across the valley of the river Trent from Muskham to Newark.

FIE points relating to the road abovementioned, referred to my confideration by the trustees thereof, at a meeting on the 19th day of December ult. were as follow:

- 1st. The propriety of the choice of the ground for the new road.
- 2d. The proper height of the road in respect of the water-line at-the extreme of high. floods.
- 3d. The proper quantity of water-way for the necessary passage of the water across the faid road in time of the faid floods.
- 4th. The particular places where the arches ought to be situated, and the number and dimensions of the arches proper at each particular place.
- 5th. The best method of construction of the said arches, so that they may be done at as little expence as possible, consistent with their being effectual.
- 6th. The proper section of the road where it passes through the grounds to be ramparted.

These are the propositions as I understand them, being verbally delivered.

- 1st. I am of opinion, that the ground marked out in the plan for the track of the new road is very properly chosen, being in general over the highest grounds, and sufficiently straight; and I look upon it to be an advantage that the arches will be as much as postible together.
- 2d. I apprehend that, to prevent damage to the road by its being overtopped, it will be adviseable to make up its crown or summit to the height of a soot above the respective water-line at the extremes of floods; and the top of the road being convex about

6 inches, the sides of the road will then be about six inches above the said water-line, which height above the water-line will also be necessary on account of the settlement, even after thrished, though consolidated in the best manner practicable while making.

In order to ascertain the respective heights of the road above the surface of the ground, a point at Newark Bridge was shewn me by Mr. HANDLEY, as that to which the highest floods were never known to rise, and which has not been touched these 30 years: from this point I took a level to a mark at Muskbam Bridge, shewn me by a person of Muskbam, as the point to which the said floods arose; from whence it appears that at medium of two operations the flood-mark is lower at Muskbam Bridge than that at Newark Bridge by 17 inches; and though this medium differed 5 inches from the extremes (which difference of the two operations was the refult of carrying the level ? miles) yet it is probable it is very near the truth, as it differs but I 1 inch from the level put down upon Mr. WILKINSON's plan in the middle of Lord MIDDLETON'S lands, between No. 18 and 19, near Muskham Bridge. The level of the high water mark upon the bridge itself was shewn me by a different person from him that shewed the high water mark to Mr. WILKINSON, therefore they probably are not the same; and I have reason to believe, that from that part of the bridge having been repaired fince the great flood abovementioned, the point shewn me was at least 6 inches lower than the real height of the great flood referred to, so that the fall of the water's surface from Newark to Muskham Bridge will be reduced to about 11 inches. I have driven piquets near the course of the proposed road, between the two bridges, to the places of which the numbers in red refer upon the plan; and having given, by a section of the tract of ground, the respective depressions of the said picquet heads below the waterline, upon a supposition of 11 inches fall of the water's surface between the two bridges, this will be a sufficient guide for the laying out and forming the road.

3d. The proper quantity of water-way cannot, as it seems to me, be determined upon any fixed principles, because it is very difficult, if not impossible, to determine exactly what proportion of water in great floods runs over the surface to that which runs through the two bridges; all that can be done, therefore, is to make the best estimation we can, rather erring by allowing too much.

It happened somewhat luckily on this head, that I passed between the two bridges in a boat at the very highest of the great flood which happened on the melting of the snow in February, 1766. I then remarked the height of the flood by a fixed mark, to which on this occasion I referred, and found that the surface of the water was then within  $6\frac{1}{2}$  inches of the height that was now shewn me at Muskbam Bridge as the highest of all. I also

also then took particular notice of the quantity of water flowing through the rails, gates, and void spaces in the hedges, and considering the great depth of the river in its own channel, and the great obstructions the flood waters met with in passing the hedges from wreck, &c. deposited therein, I cannot in my own mind suppose that the whole water passing over the surface of the lands could equal that which passed through Muskham Bridge alone; but, that we may err on the safe side, let us consider the capacity of both bridges. Having, on the present occasion, taken dimensions of the water-ways of both bridges, and compared them with the length of the arching that will be equivalent thereto, upon a supposition that the flood arches upon an extreme flood carry a depth of water upon their floors of 6 feet at a medium, I find them as follow:

		Yards running.
Muskbam Bridge equal to flood bridging	_	154
Newark ditto — — —		99
Equivalent of both bridges in flood bridging		253

In order to check the above, I tool selfimatory account of the whole openings in the line of the hedge on one fide the patent road through which all the flood waters must pass that run over the surface of the lands, and make them amount to an equivalent of flood bridging of 333 yards.

Now the mean of the two determinations will be 293 yards, but for a round number let us fay 300 yards, which is near ; more than the fum of the capacities of both bridges: now this quantity, properly disposed of, will, in my opinion, be amply sufficient for discharging the slood waters, without the least danger or detriment of either sticient for discharging the slood waters, without the least danger or detriment of either the lands above the road, or to the road itself; and if the expence should make it need the lands above the road, or to the road itself; and if the expence should make it need ful, I am of opinion that the quantity above mentioned may be retrenched.

4th. The next article is the proper disposition of the arching above mentioned; and on viewing the face and levels of the country, it appears that the places where the flood-bridges now are, viz. at Crankley, and the three bridges, are the principal outlets for the flood waters. This experience has taught our forefathers, as is manifested lets for the flood waters. This experience has taught our forefathers, as is manifested lets for the flood waters in those places; it follows therefore that those natural hollows, by their placing bridges in those points, will be the properest places for the new flood-which lead the waters to those points, will be the properest places for the new flood-which lead the fame time disposing of some arches or tunnels quite through the whole, bridges, at the same time disposing of some arches or tunnels quite through the whole, to prevent any water remaining pent between the hedges in any particular place.

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The arches I would recommend are of 12 feet wide, and 6 feet from the floor to the springer; they may be nearly all alike, except that in such places as will admit thereof, the floors may be laid lower, and the piers raised higher above the soundation than before specified, in order that one with another they may be of 6 feet depth of water I for lesser communications, I would propose tunnels of 5 feet width, covered by semicircular arches, the depth from the crown to the floor to be 6 feet, and the crown of the arch on the under side to be 2 feet 6 inches under the crown or summit of the road. According to these dimensions, three of these tunnels will be equivalent to one of the arches.

# The places of the arches and tunnels as follows:

			Extent i	
	Arches.	Tunnels.	Yards.	Feet.
In the low ground between the north end of Newark Bridge, and the				
higher grounds opposite the warehouse,	9	0	36	
In Mr. Ridgell's close,	2	2	2	2"
In Thomas Wood's ditto,	0	1	1	1
In James Hanker's,	0	2	2	3
Cross the valley at the three bridges	24	0	96	0
The further hollow in Mr. Stevenson's chose, where the piquet, No. S,				
	0	3	4	0
is placed, In the drivers, where the piquet, No. 12, is placed,	0	1	1	1
In the great hollow from the drivers to Langdale, crossing the water-				
course that leads to Crankley Bridge,	24	0	96	0
In the low flade in the rector of Kelbam's ground at No. 16,	6	a	24	0
In the low hade in the fector of income a grown and and	3	0	12	鹽
In the crossing of the old road, In Lord MIDDLETON's land, near the fouth end of Muskham Bridge,	3	0	12	B
Between Muskham Bridge and the high land at the north end thereof,	3	o	12	0
Between Mujenam Briage and the ingit tand at the morning		-		
	72	9	300.	

The above is the best disposition I can form for the placing of the water-ways from my own observations and the information I have had; but as the going away of the present snow may probably surnish a good opportunity of making observations upon the currency, it would not be improper to appoint a discreet person for that purpose. I am opinion, however, that if the arches in those two places, which are laid out for 24 arches each, were reduced to 21, the water-way would be very ample.

5th. With respect to the construction of the arches, having explained myself by a design, I have the less to say thereon: it is necessary however to observe, that respecting

the foundations, I have supposed it so firm gravel or clay, at the depth to which it will be necessary to excavate; but where it proves a soft clay, loose gravel, or sand, or still softer matter, it will be necessary to pile under the piers. In ordinary cases, piles from 5 to 8 seet long, and from 6 to 8 inches diameter, driven about 2 or  $2\frac{\tau}{2}$  seet distance, middle and middle, will suffice; but as nothing can be ascertained on this head, without trial of the individual spot of ground in question, and as the sirmness of the ground will frequently vary one pier from its next neighbour, the quantity and size must be increased or diminished, at the discretion of the surveyor.

Where piles are not used, I propose the first course of bricks to be set edgeways upwards, the length of the bricks crossing the base of the pier, the whole to be driven down with a paviour's rammer in the manner of pavement, and after that the interstices run full of grout or putty, or if wet, to be filled with quick lime. If piles are used, bricks or half bricks to be drove down in the same manner in the interstices between the pile heads, and then to begin the regular courses upon the paving and pile heads promiseuously, being grouted as before. It is hardly necessary to say, that where a good soundation can be come at by going deeper, at a less expence than piling, it will be proper to do it.

As the arches are proposed to be but 12 feet wide, in order to avoid an unnecessary quantity of brick work, I have supposed the shafts of the piers to be but  $2\frac{1}{2}$  bricks thick, which, if built sirm inside and out, will be very sufficient to carry the loads in such short spans; the arches themselves I have supposed to be no more than one brick thick, which I am also satisfied, if well done with good materials, will be quite sufficient: yet, as the supporting parts in the elevation have somewhat of a light appearance, if to satisfy the eye the trustees think it proper, half a brick may be added to the piers, and also half a brick to the arches within, which will make but little alteration in the design.

To fave expence, I have supposed the whole to be of brick, the cap stones for the terminating pillars of the parapet excepted, which are necessary to be of stone, on account of weight to keep on the brick caping; but if the expence can be admitted, it would give the whole a more substantial appearance to those who travel the road, to would give the whole caping of stone. I suppose that the shoulder angles and springers of the have the whole caping of stone. I suppose that the shoulder angles and springers of the piers, together with the capings, if of brick, to be made of their proper figure in moulds for that purpose.

To make all the piers thick enough to support all the adjacent arches single, without the counterbalance from the neighbouring arches, would bury a large quantity of materials;

terials; I have therefore adopted the thought of my ingenious friend Mr. MITCHELL, in making every third pier or every fifth strong enough for this purpose, that in case of accident the damage may not be progressive.

6th. In regard to the proper section of the road, it appears from the general section, that the slat ground from the point No. 4, to the three bridges, is the deepest slooded of any part that will be done by ramparting, and that the depth at a medium below the water's surface is 4 feet, the mean height therefore of the crown of the road will be 5 feet; and for this height a section is drawn, shewing the excavations necessary on each side, in order to surnish matter to form it when consolidated; but if the bottoms of the canals on each side do not afford gravel for a cover, then the excavations may be of less width on account of this part of the matter being brought from a distant place; but whatever be the height of the rampart, the same section will regulate it, by supposing the top of the road and angle of the slopes on each side to remain the same, and therefore the width only of the base to be variable, according to the quantity of matter required.

I suppose that in a sew years the ditches will filt and grass over so as to become pasture land, but as it will not only be unavoidable, but in some measure useful for the water, in time of great floods, to have a current along those ditches, it will be proper, as early as possible, to sow them with hay seeds, to prevent their sides from slipping, or from being galled by the current while they are new.

In order to prevent the surge, which in time of great floods will be raised by the action of the wind from washing down the sides of the rampart before it can get simily swarthed over, it will be necessary to set the slopes of the ramparts with sods, in the manner shewn in the section; and if the slope of the ditch next the rampart, as well as the opposite side where it saces the arches, was sodded also, it would be still better.

I have drawn the section of the road so as to afford a breadth of 30 seet for the tread of the wheel, which I apprehend will be quite sufficient, especially where the rampart is raised high, as well as in the bridging; but in the high grounds, where the road is to be but little raised, it will not be necessary to be confined to this width.

Austborpe, January 11, 1768.

J. SMEATON.

#### GLASGOW BRIDGE.

Copy of a REPORT delivered at Glassow by Mr. SMEATON, in October, 1760, from a copy thereof received from Mr. Murdock in a letter, dated April 20, 1768.

Report concerning the situation of the intended new bridge over the river Clyde at Glasgow."

HAVING carefully examined the river at seven different places, viz. 1st, opposite Jamaica Street; 2d, at the middle of the island, commonly called Ducat Green; 3d, in a line passing behind the Gorbal church; 4th, in a line agreeing with the street that runs before the Gorbal church; 5th, at the present bridge; 6th, at the slaughter-house, in a line with the new street; and 7th, at the Green of Glasgow, almost opposite to the gate leading from the bottom of the Salt-Market, of which a particular account is contained in the paper annexed, from whe it appears to me that the fituation of the present bridge is not the most eligible, 1 e following reasons: 1st, On account of the greatness of the length which will increase the expence; 2d, by the street answering thereto on the Gorbal side being too narrow, and embarrassed for the main avenue to a bridge of 30 feet wide; that street being not above 22 feet at a medium, and in several places not 18 feet; 3d, because it would not be sase to build a new bridge in the same place, except conformable with the old foundations, which would subject the new bridge to great irregularities; for as the present bridge appears to be sounded upon the surface of a crust of gravel, covering mud or sleech to an unknown depth, was the new foundation upon the interitices, and the old ones removed for the fake of giving a free passage to the water, as this crust is undoubtedly broke through in many places by piles, &c. it would be dangerous to remove them, lest, by giving advantage to the speats to gull away the ground from thence, a free passage is given to the mud to escape, and thereby to render the new pier liable to settlements. 4th, The disadvantage of wanting a bridge during the time of building a new one, or the charge of a temporary bridge balanced against the small value of the old materials, are too obvious to need insisting upon. 2d, The position agreeing with the front of the Gorbal church is not the most eligible on account of the great length between the top of the bank on each fide, so that it would require the extent of the bridge to be greater than its present situation; and as the north end would abut upon the workhouse dyke, would be too near, and too confined, without an opportunity of forming any new street in any good direction from thence, nor is the avenue from the fouth abutment free from objections, being but 27 feet in the widest part, and not above 19 opposite the church wall, which would require to be removed. and some private property purchased; nor is the cross street leading to the turnpike less exceptionable.

3d. The position agreeing with a line passing behind the Gorbal church, will clear the fouth abutment of all incumbrances, and mend the north in regard to the practicability of making an opening into the green beyond the row of trees called the Old Green; but till that is done will be as much confined as the former, nor will this situation admit of any street in any good direction into the town, without passing through gardens and private properties; add to this, that here the bridge will be required the longest of all, the distance from the tops of the banks being upwards of 600 feet.

4th. To the position agreeing with Jamaica Street, are the following objections: the bottom is worst of all, and the water deepest, nor does the line of this street produced cut the stream at right angles, which is a disadvantage that ought always to be avoided if possible; but without insisting on any objection to this situation on account of its being too near, and too much confining and embarraling the present wharf or landing-place, or on account of its being too far removed from the present bulk of inhabitants, the foundation is a matter of consequence, for though the mud or sleech that lies under the bed of gravel is much of the same consistence as above (if any thing more soft), and may be made capable by proper care and caution of bearing the superstruction of a bridge; yet as the upper crust is considerably thinner, and less compact than above, it is justly to be apprehended that when the channel comes to be contracted by the piers, the increase of velocity of the water, in time of speats, may take away the bed of gravel between the piers, and by laying the mud exposed to the action of the water, may produce fatal consequences upon the adjoining piers, and this cannot be prevented but by a considerable addition of expence in the original construction, in piling, setting, and framing the whole of the spaces between the piers.

5th. At the slaughter-house, in a line with the new street, the river is of a moderate width, the running fand below the gravel lies the closest I ever met with at that depth; yet as the upper stratum of gravel is but loose, and the under crust very thin, this soundation is not without suspicion on account of the speats, nor does the line of the new street make a right angle with the stream of the river | fo that after pulling down several houses in order to open an avenue thereto, the direction of the bridge cannot properly stand in a continued line with the street; the avenue on the south side will also be embarrassed in passing the Gorbals, for after pulling down some houses to make an avenue answerable

answerable to the cross street leading to the turnpike on Paisley road, that street itself is in many places not more than 16 or 17 feet wide.

6th. The foundation at the green at Glasgow, opposite the gate leading from the Salt-Market, is much the same as at the slaughter-house; the objection with respect to a pasfage through the Gorbals the same; the avenue from the bottom of the Salt-Market might be somewhat enlarged, by removing the garden wall, but the clear between the houses in the narrowest place is not more than 251 feet.

7th. It now remains that we examine the position at or near the middle of the Ducat Green; the width of the river between water and water is least of all, being at the boiler 345 feet, and from the top of the bank on the fouth side, to the top of the high ground on the island, 495 feet; from that point measuring across the Green, to the middle of the road down the avenue of trees, is 180 feet 1 from the top of the bank on the fouth side, to the Paisley road in a direct line through the arable ground, 600 feet, which, allowing the breadth of the road to be 40 feet, will scarcely amount to half an acre Scots: in this position the new bridge will be about 900 seet distant from the present bridge, unembarrassed at either end, and capable of jerning a new street that might hereaster be made across the Old Green, which may be mad in a right line upon an arable close, and join the Troangate-Street near to Mr. BUCHANAN's house, without interfering with any present buildings or gardens. The obliquity of the stream of the Clyde with the line will indeed occasion the position of the bridge not to be in the same line, but the obliquity will not be fuch as to occasion any material inconvenience with respect to the useful part. The foundation at this place, though not perfectly the best, is yet as good at bottom as any, and the bed of gravel as thick, and in general as compact as any, but the upper crust for about 8 or 9 inches not quite so hard as at the ford opposite the Gorbal Church, and at the present bridge, but much more compact than it is lower down; however, to remove all objections on account of the ground, I would propose to make the sum of the openings of the new bridge equal to the span of the river in that place; and consequently, as the velocity of the water in time of speats would not be increased, there is no reason for supposing that the said gravel that now sustains their efforts, will not continue so to do; and this may be done two ways, 1st, by digging away so much of the fouth side of the Ducat Green next the river as shall be equal to the sum of the solids of the bridge, and with the earth to fill up the back drain; 2d, by fetting the abutments a little within the land on each side, and to procure a further addition of free passage by widening and deepening the back drain, over which I would throw a fingle arch. The

It therefore seems to me that this situation of a new bridge will, upon the whole, be attended with the least inconveniences, be executed at the least expence, suit the conveniences of the present inhabitants, and favour any improvements that may be made further.

(Signed)

J. SMEATON.

Glasgow, October 20, 1760.

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proper place for the intended MEATON relative 17th of new bridge at Glafgo Soundings, and Obfe Meafures,

Qualities of the fold in the middle of the river to so feet deep-	3 feet of loofe channel, below mud or fleech.  5 feet of good channel, below ditto.  4 feet of good channel, below ditto.  1 foot of hard channel, 3 feet loofer ditto, and mud below.  5 feet loofe channel, 1 foot hard ditta, below a running fand.  9 feet loofe channel, 1 foot hard ditta, below a running fand.  Ditto.
Depth.	2 2 3 1 1 2 3 3 1 1 2 3 3 1 1 2 3 3 3 1 1 2 3 3 3 3
Sua.	468 405 405 580 580
men of c	50 50 50 133 133
span of the Suge It the top of criver water Onthe South. On the North	Feet. 100 150 68 215
pan of the river water and water.	384 345 345 345 389 360 370
201	2d. At the upper boiler on the illand, 3d. Behind the Gorbal church, 4th. Before the Gorbal church, 5th. At the prefent bridge, 6th. At the flaughter-house, 7th, At the Green of Glosgow,

N. B. The general height of the b

47

Measures,

# DUMBARTON BRIDGE.

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## WHITEHAVEN HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon a View of the Harbour of Whitehaven.

HAVING carefully viewed the harbour of Whitehaven upon the 7th and 8th of April, 1768, I am of opinion as follows:

That in case the expence and length of time attending such a work would permit its execution, that the noblest and best scheme would be to carry out a north pier, and to lengthen the new pier, tille the heads of the two piers should be within a competent distance (suppose 200 feet) of each other; but as I apprehend it would be many years before much relief could be procured to the trade by so extensive a work, the most ready way of enlarging the harbour would be by extending the old pier by some additional works, the particulars of which it will require leifure to judge of; but I am clearly of opinion, that if during the coming fummer the old pier can be lengthened 30 yards, and turned a little more outward than the present direction, it will perfectly agree with every just idea of what is to follow, and that the prolongation aforesaid should be the first work done; and if during this time a correct plan of the harbour, piers, and appurtenances, together with the coast as far as Redness Point, is prepared to be laid before me, I shall then be in a condition to judge more accurately of what is to follow.

Cockermouth, 8th April, 1768.

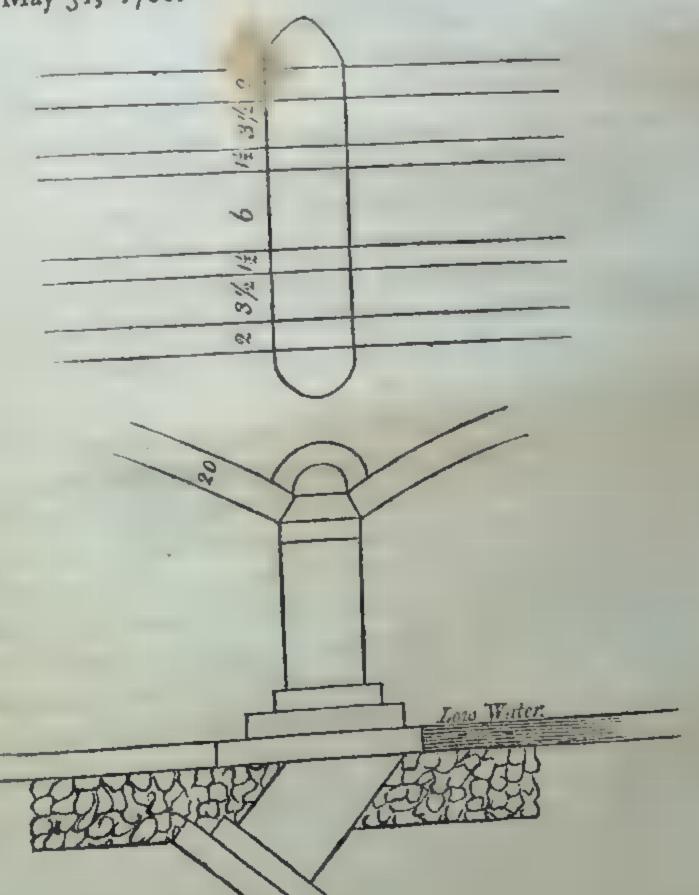
The REPORT of JOHN SMEATON, Engineer, upon the rebuilding the funken pier of Dumbarton Bridge.

Having viewed and examined the funken pier of the bridge of Dumbarton, and the nature of the ground upon which it stands, and finding that it is a soft mud to a depth unknown, it being tried to the depth of 46 feet below low water mark, I do not know of any certain method of founding in such a situation; but, considering the very great difficulty and expence that will probably attend the taking up the present work to the bottom, being about 17 feet below low water mark, and the great uncertainty of better success, if that could be done, I am of opinion that the best probable chance of success is to found a new pier upon the ruins of the old, and to make the superstructure as light as possible; the particular methods of doing which I have pointed out to Mr. JOHN BROWN, mason of the said bridge; and as the other piers and arches seem to stand firm. I think in the above way there is so far a reasonable prospect of success as to deferve to be attempted.

Dumbarton, May 31, 1768.

J. SMEATON,

LEWES



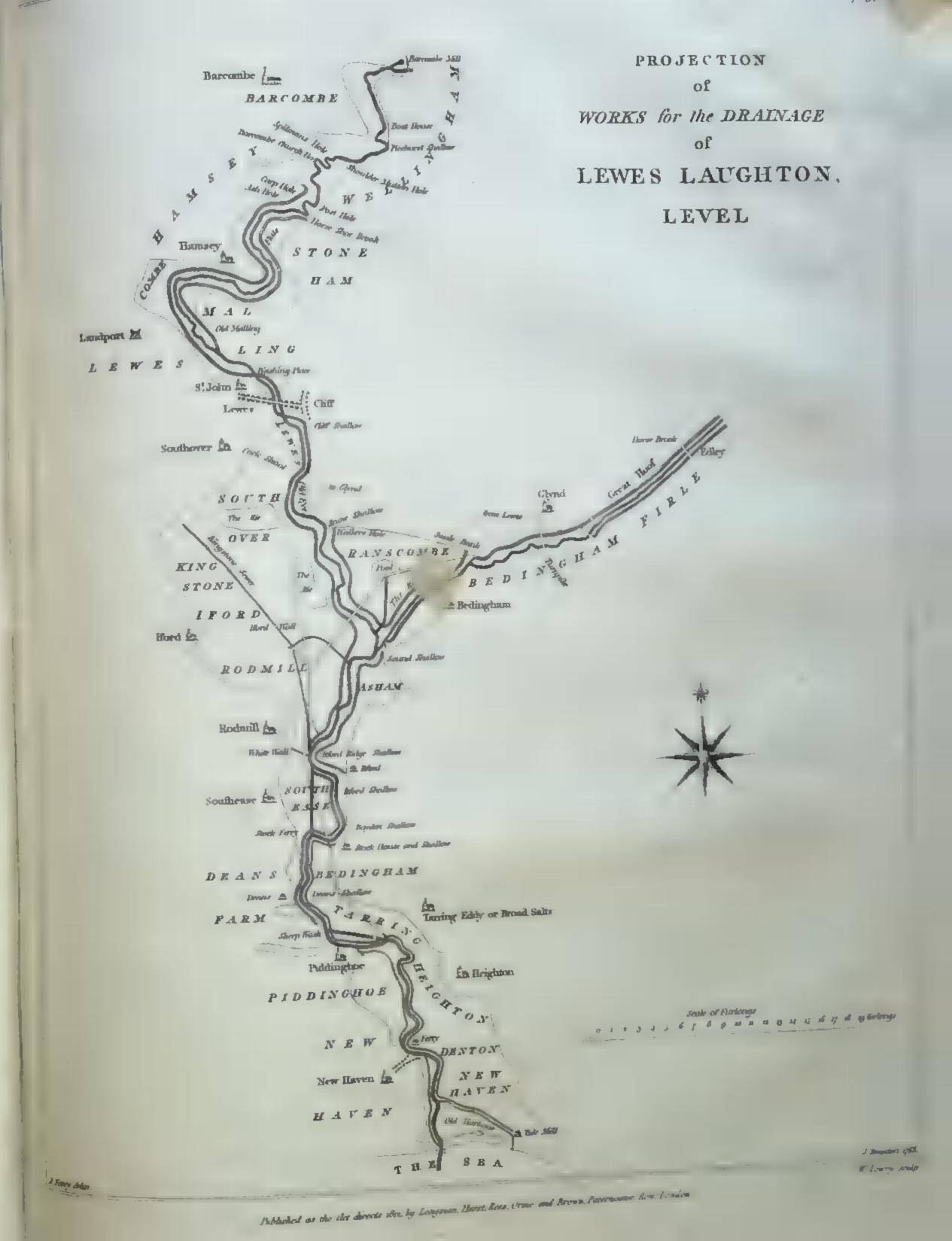
#### LEWES LAUGHTON LEVEL.

The REPORT of John Smeaton, Engineer, concerning the Drainage of Lewes Laughton Level, in the County of Suffex.

HAVING carefully viewed and examined the state of this level, upon the 17th, 18th, 19th, and 20th days of June, 1767, I found its condition as follows:

The preceding part of the feafon having proved wet, the level meadows called Brooks, laying upon the river Oufe, were in general under water from Land Port, above Lewes, to White Wall, below Redmill. I observed that the surface of the water in the brooks of Southover, Itford, Pool Bar, Shine, and Rodmill, was nearly upon one common level, which feveral tracks of ground, for the eafe of express in, I beg leave to call by the general name of the West Level: That there was but an inconsiderable fall of the furface of the water from the west level into the river, when the tide was down, and was some inches below the surface of the river when the tide was in: the same observation equally applied itiels to Ranfeembe. That the artificial banks or walls contiguous to the river bordering on both these levels, were low, and in very bad condition, so that if the river was to swell 6 inches higher than it then was, the two levels and river would have one common furface. I observed, at the same time, that the lands below White Wall, from the fouth-east downwards, on the west side, and those of Tarring on the east, were in general dry, and in a tolerable state of drainage, which preferable condition thereof was undoubtedly owing to these three causes: the land itself is considerably higher, the banks made up higher, and in better repair; and their out-fall fluices fixed lower upon the river, which in confequence affords them a better fall.

It was observable during my stay, the tides being then in a mean state betwixt spring and neap, and the river pretty sull of water, that the tides were scarcely sensible at Lewes Bridge, and but a few inches rise and fall at the mouth of the river Glynd; while at the sheep-wash above Piddinghee, the tides rese and test 5 feet, and not above half a mile below, at the head of the Broad Saits, the rise and fall was near 8 feet; the greatest part of the whole fall lying betwixt the last-mentioned place and White Wall, a space not above  $2\frac{1}{2}$  miles, according to the gourse of the river, and which includes at least  $\frac{2}{3}$  of the whole fall, from Lewes Bridge to the head of the Broad Saits, which is a length of near 7 miles. This great declivity in the river from White Wall to the Broad Saits is doubtless owing to a series of shoals laying in that space, the principal of which is Piddinghee, which alone occasions a fall of 3 feet, and which, as well as the narrowness and winding



winding course of the river, altogether occasion the holding up the water in the river above White Wall, and which in confequence oppresses the levels laying thereupon, and fill the more in proportion as their natural furfaces lay 2 feet at an average lower than the grounds below White Wall.

From the head of the Broad Salts downwards, the river is more spacious and open, and wherein the tides have full liberty to flow and reflow, and may be confidered as an open tide's way. The declivity of the furface at low water is very gentle, till we come near the harbour's mouth of Newbaven, where the river Oufe falls into the fea, and where the water is held up by a bank of shingle, thrown in by the great seas and tides, and in part washed out again by the united force of the freshes and reflux of the tides, and which finds a balance betwixt these contrary powers, being somewhat variable according as one or the other happens to have the prevalence. From the furface of the water above this bank or bar, that is, from the furface of the water in the pool where the Thips lay, called Sleeper's Pool, I found a fall of 61 feet to the low water mark at fea, which at spring tides is still greater.

The state of the brooks above, on one of Lewes Bridge, and which for the sake of a general name I beg leave to call the Worth Level, was as follows: they were almost entirely under water, as high up as Land Port; from thence up as high as Iron Hole, they were in part under water; but in general where no water upon the furface, low and moith, and the appearance of being oppressed with water a too great length of time; but from thence to Barcombe mill, the meadows lay considerably higher, being in general 3 or 4 feet above the furface of the river, as it then was; however, as the whole course of the river through the North Level, from Barcombe mill to Lewes Bridge, has but an inconfiderable fall, is very crooked and winding, and in some places obturucted with shallows, the upper as well as the lower part of this level must be subject to be should on moderate down-falls of rain.

With respect to the brooks upon the river Givnd, eastward of Ranfeemie, they appeared to be in general above water, but yet subject to too great a continuance of thagnant water upon them, partly from want of a fufficient fail in the river Gund, and partly from crookedness and obstructions therein; however, as they appeared in general fo much higher, that by whatever means the drainage of Rangiands would be effected, must necessiarily furnish the means of draining those brooks, I was less solicitous about the exact state of particulars.

It appears moreover, from trying the different depths of the water in the different breoks, that the deepest under water were Ranscombe on the cast side, and the S. E. part of Itford and part of Redmill brooks in the west level, the general surface of those low parts being then about 3 feet under water.

From this general view of the state of the level, it would seem, that if the obstructions arifing from the several shallows from the narrowness and crookedness of the river, between the mouth of the river Glynd and the top of the Broad Salts, were removed, which have been described to be the cause of the holding up of the river at and above the aforefaid limits, that the consequence would be a general drainage of all the levels; and it is certain, if these things were done, that this alone would be a great help to the whole of the grounds in quellion; but yet, as the taking away these obstructions would in consequence les the tides flow in with more rapidity, the natural declivity of the river being small, there would be scarcely time for the tide and fresh water to evacuate itself, before another tide would return, and thereby prevent its ever running so low as to admit of a compleat drainage of the adjacent levels.

Towards an effectual drainage of these levels, two methods offer themselves; one is to straighten the river, and remove all obstructions as before described, and furthermore, to prevent the tides from having the effect abovementioned, to place a large out-fall sluice at its entrance into the open tide's way, with gates to shut out the tides from flowing up the river, and of fufficient dimensions to discharge the fresh waters at their greatest extream; and lastly, to embank Ranscombe and the west level against the overflow of the land floods, so as to convey the flood waters directly to sea, placing sufficient suices upon their respective out-falls into the river, so as to shut out the land floods, and give an opportunity of drainage when these floods are run off, which they will easily do, when not suffered to spread upon the adjacent levels; and indeed, without embanking those levels as aforesaid, every method of drainage will be no more than a palliative help.

The second method supposes the river to remain in its present course, or without great alteration, to embank the lands to be drained against all extreams of floods, and to convey their internal down-fall waters by a separate canal or sewer to the open tide's way, with a fluice upon the out-fall of the faid canal, to prevent the reflux of the tides.

Each of these methods have their particular advantages; the first seems better adapted to give all the succour possible to the All Country dependant on this out-fall; the second is more particularly adapted to the drainage of Ranfcombe and the west level, the north and east levels being less advantageously situated by nature for drainage this way, as will more particularly appear from a further description and estimates that will follow of each method.

From an accurate level taken the 18th and 19th of June last, it appears as follows: Fret In. Rife from low water to the head of Broad Salts, to the furface of the water in the west level, The river being then charged with fresh water, the low water surface at Broad Salts was faid to be 2 feet, at least 18 inches above its low water height in dry seasons, but taking it at Rife from low water at the Broad Salis in dry feafons to the furface of the water in the west level, The mean depth of water in the low parts of the west level and of Ranfrombe, (subtract) Rife from low water in dry featons at the head of the Broad Sales, to the mean furface of the low parts of the well level and Ranfcombe, - - - - -Now in order to produce a compleat drainage of those low grounds, it will be necessary to reduce the furface of the water, below the furface of the ground,

There will then remain

It therefore appears that the water may, in dry seasons, be retained in the river 2 feet 5 inches above low water in the tide's was and yet the furface reduced full 5 feet below the height it was in June 1767; and as the deepest parts of the pool in Ranscombe (which is deepest of all) sounded only 4 feet 6 inches, it follows that the water may be reduced in the drains 6 inches below the bottom of the pool in Ranfcombe.

In regard to the 2 feet 5 inches of water retained in the river above low water, it will be useful for navigation in dry seasons; and in small freshes, by affording so much fall, will thereby give the river a better current to sea, without overcharging the drains. In larger freshes, and great downfalls, the river's water will be prevented from over-riding the drains by their respective sluices, and the water will quickly discharge itself to sea, on account of its being confined between the banks, which are proposed to be made to prevent the rivers from overflowing the adjacent levels, as they do at present.

To effect these purposes, I would propose a new cut or river to be made across a cor ner of Tarring Tenantry, by within means Pidainghoe shoul will be avoided: a sluice is to be placed at the tail of this cut of three passages, 2 of 13 and 1 of 14, containing in the whole 40 feet clear water-way; the latter passage to be furnished with a double pair of pointing doors to seaward, and ditto to landward, for the sake of navigation; the other passages each to be furnished with a single pair of pointing doors to seaward, to shut out the tides, and a single pair to landward, to retain the fresh waters at a given height in deg seasons.

A dam to be put across the river at Piddingboe sheep-wash, so as to shut out the tides, and to prevent the sloods from passing that way after the aforesaid works are erected.

In order to avoid a crooked part of the river in passing by Itsord and Stockhouse, containing a number of shoals, I propose to cut a new river from Stockserry to the turn below the It bite Well, of the same dimensions as the former.

All the other shoals I propose to deepen, so as not only to lower the surface of the water at Lewes Bridge from 4 to 5 seet, but also to make full 3 seet 3 inches water over the shallows in the driest seasons, which will be a great improvement to the navigation, as vessels will not be stopped by neap tides in dry seasons, nor obliged at any time to wait for the tides betwixt the sea sluice and Lewes.

These works being essected, all the levels in question will be in a capacity of drainage, that each performing the particular works that relate to themselves, the whole will be in a condition of improvement.

As the west level and Ranscombe lay considerably lower than the rest, it is impossible they should be in a good state of drainage without being embanked against the freshes and shoods of the river Ouse and Glynd; but instead of setting the banks close upon the river, I would, in the general, leave a space of 50 seet between the bank and the river, however varying this quantity, so that without following the sudden turns of the river, the bank may be reduced in length; observing, that where the bank is near the river on one side, it be put further off on the other, still forming an open space to give room for the passage of the sloods in wet seasons.

According to this method, there will still be a necessity of sluices for the particular drainage of each tract of embanked land, to shut against the river in time of floods. Those already constructed might have answered the purpose had their thresholds been laid low enough, but as the thresholds of Shine and Ranscombe sluices, which lay the lowest, are at a medium but about 2 feet below the mean surface of the lowest lands respectively, they are insufficient for an effectual drainage, because before the water can come down to its proper pitch of level for drainage, its thickness over the thresholds will be so much diminished, as not to afford the water a sufficient passage. I therefore

• It is to be observed, however, that if there should happen to be any solid objection to putting a dam across the river at Piddingbox sheep-wash, that the same purpose may be effected by putting sluices, instead of a dam at the sheep-wash, in which case there will need no more than the 14 foot passage for the joint purposes of navigation and drainage upon the new cut proposed across Tarring brooks.

recommend a new sluice of brick for the west level, to be placed down as low as the White Wall, and another for Ranscombe, near the mouth of the river Glynd, their thresholds to be laid 2 feet lower than those of the sluices abovementioned respectively.

In regard to the internal drains, what will be wanted further will be in the west level, one to join the sluice at King stone sewer, which sewer, when properly scoured out, will drain the western parts of the level; and those parts laying near the river, as far north as Cocksbutt, will be drained by the back drain, which will of course be formed, by taking the matter for embanking. In Ranscombe a new drain must be made, or the old ones scoured out from the sluice to the pool; but the back drain of the bank will be an effectual drainage for all the parts of the level near the river.

This is the whole, therefore, that can be expected to be done at a joint expence in these two levels; the division and other drains are to be made by the respective proprietors, at their particular expences, and which I don't consider as any part of the object of this report.

At the time of my view the river had but an inconsiderable fall from Lewes Bridge to the mouth of the river Glynd, so that when the shallows are removed, the water in the river, as already mentioned, will, in its ordinary state, be reduced 4 feet at Lewes Bridge below what I found it \*, and sometimes near 5, so that in the Lewes brooks above Cocksbutt, the ordinary surface of the water in the river will be about 3 feet below the surface of the land; and in the brooks north of Lewes Bridge from 3½ to 4 feet and upwards; so that, taking away some shoals above bridge to facilitate the passage of the water, I look upon all these brooks as in a state of drainage, liable, indeed, to be overslowed upon great downsalls of rain; but as, according to this construction, these downsalls will speedily run off, and leave the meadows dry, they will be slittle banking or drainage will be further necessary for their security, I suppose to be left to the discretion and management of each particular proprietor.

The same reasoning will hold with respect to the brooks upon the Glynd, east of Ranscombe, for the water being reduced from the surface, I sound it sull 5 seet perpendicular at the out-sall of the Glynd into Ouse, there will be little surther to do, than to dicular at the out-sall of the Glynd into Ouse, there will be little surther to do, than to dicular out the river Glynd, so as to take advantage of the salls so obtained; the scouring out of the river Glynd I look upon as a work particular to the brooks east of Scrale ing out of the river Glynd I look upon as a work particular to the brooks east of scrale

The water under Leaves Bridge, when the levels were taken, was 3 feet 81 inches below the top of the aisler courses of the S. E. wing of the bridge.

\*\*The water under Leaves Bridge, when the levels were taken, was 3 feet 81 inches below the top of the Bank;

Bank; and what further banking and draining may be necessary, I in like manner suppose to be the work of the respective proprietors, and not the object of this scheme, which is to point out the general methods by which the whole will be put in a capacity of drainage, not to drain the lands, ready for the husbandman.

I have already shewn that the work of the drainage thus constituted will be advantageous to the navigation of the river for the barges, and an advantage for which, in my opinion, they ought to pay a toll towards the eafe of the general undertaking: it now remains to shew that the constructions proposed will be no ways detrimental to the harbour of Newbaven; on the contrary, I propose to demonstrate, that it will be a considerable advantage, upon the principles of the first scheme now described, for as to the second it cannot be made a question.

I know it will be immediately apprehended, that the tides being stopped at Pidding. boe, will occasion a less influx of the tide at the mouth of the harbour; and as a less influx will produce a less reflux, the power will thereby be diminished, by which the fand, shingle, &c. is driven out to sea, that is brought into the harbour's mouth by storms and hard gales of wind bearing strong upon the coast; but this reasoning, however plausible it may appear, and however true it may be in some cases, yet in the present it will not hold; but I must observe, that if admitted, the quantity in question is so small in proportion to the whole, that its effects can produce no sensible difference in the scour of the harbour; the quantity of tide water then in question will be only such as flows into and out of the river above Piddinghoe shallow; this, at the time I was there, amounted to a rife and fall of 5 feet, as already stated at Piddinghoe sheep-wash, but at White Wall, not 21 miles up the river, the rife and fall were not above a foot, and at Lewes Bridge scarcely sensible, so that the greatest part of the influent water was contained in about 21 miles of river, at the mean depth of 3 feet, and at a mean width not exceeding 30 or 35 feet \*, which will evidently bear but a small proportion to the water contained in the river from the pier of Newbaven to Piddingboe, where the mean rise and fall was three times as great, the mean breadth more than double, nearer three times, and the length above three miles, besides the water-slowing a considerable breadth near a mile up the old harbour, as far as the tide mill: this would be the proportion, supposing all the tide's water above Piddinghoe to be quite lost; but the real quantity of reflux lost by the river above Piddinghoe will be greatly diminished, below what is

above

above stated, when it is known that the tide at Piddinghoe did not rife so high by above a foot (I made it I foot 3 inches) as it did at the pier head the same tide; from whence it follows that the tide having room to spread and spend itself faster than it can be supplied at the mouth, the ponds within are never filled within 6 or 7 inches at a medium so high as they would be if they were so much less, to have time to fill to the level of the tide at fea: we have therefore grounds to fay, that if the tide was prevented from spending itself so sar up the river, it would occasion the remaining space to fill to a higher level, and thereby take in a quantity upon the whole nearly as large as if fuffered to flow further; and that this reasoning is true, further appears from this fact, that in spring tides the water gets so far up the river, that not having tide to get back again, the same tide fills the river above White Wall fuller and fuller, which is not evacuated but by the neaps that succeed \*.

From what has been faid we may be affured, that the stop of the tides at Piddinghoe could be of no great consequence to the harbour, even upon a supposition that the tide water there lodged is useful towards clearing the harbour's mouth, which I come now to shew that it is not, but in the present case detrimental.

When the wind is in shore, and brings an heavy sea upon the harbour's mouth, the shingle is thereby put in agitation; and if a strong tide of slood happens during such violent agitation, the indraught of the tide brings in a quantity of shingle, and loads the entry of the harbour, and this effect will (cateris paribus) be greatest when the indraught is strongest, that is, when there is the greatest tides, and the least fresh water in the river to oppose them; and this indraught will also be strongest, when there is a narrow entry, and great space wherein the water may expand itself, for there the tides of flood will set in through the harbour's mouth the most rapidly. These circumstances concur in a strong degree in the present case, and therefore a diminution of their expansion must diminish the rapidity of tide of flood; at such a time when the river has no great currency downwards, the tides, as already observed, instead of returning wholly to sea, are spending themselves up the river to Lewes, which occasions a rapid influx, and a languid efflux; the river is therefore at this time in no condition to evacuate the shingle so brought in; here it must lie till something happens to turn the balance the contrary way, and this is done by the land floods joining with the tides, which promote a brisk reslow to sea. Now at such times, the land stoods will at Piddingboe over-ride the tides, and the sluice doors will be open the whole time of tide; the sluice therefore will not in any respect impede the land floods from getting to sea, and by the embanking

I am sensible that in dry seasons, when there is less land water in the river, the rise and fall of the tides will be greater, and be fensible further up the country; but as the efflux will be less for want of the land water, the effect in scouring must be less than at the time above stated.

<sup>.</sup> N. B. The high water before referred to was near 1 foot higher at Piddinghoe than it was at Lewes Bridge.

of the river, they will be brought down with greater rapidity, and thereby produce foour superior to what it can obtain in the present state of things. Since therefore the rapidity of the tide of slood will be diminished, and the ebb tide increased, at such times when alone they can be of use in scouring, the effect upon the clearing of the harbour's mouth must be beneficial \*.

I come now to describe the second method of drainage, whereby the river will be left in its natural course; and whereby, if the drainage of the west level and Ranscombe were the only objects in view, the work would be done at the easiest expence, as will be more-particularly seen by the estimates.

This consists of an entire embankment of the rivers against all extremes of sloods, so far as the drainage is carried, thereby shutting the river entirely out; so that instead of discharging the down-fall waters into the river at the point opposite the respective tracts of ground, it is to be collected into one drain, and finally discharged into the open tide's way by means of a sluice, which, shutting out the tides, prevents at once the reversion of the water for the whole level. This sluice and drain will be far less in point of waterway than that before proposed, having nothing to convey to sea but the down-fall water of the levels to be drained; thereas the other must be large enough to afford a sufficient passage to sea to the flood waters of the whole river in the greatest extremes of floods. This second method is in many cases to be preferred, as it stands clear of all difficulties respecting the altering the current or navigation of the river, and is in itself most persent; but in the present case the north and east levels are situated so disadvantageously, with respect to their communication with the general out-fall, that to accomplish the whole in this way will be more expensive than by the first method. But to proceed:

I propose the out-sall sluice to be nearly at the same place of the river as before proposed, and to be of 12 feet water-way; from hence a drain of 12 feet bottom to be carried through Tarring Tenantry, and by means of a subterraneous tunnel, to cross the river Ouse in a proper point between Stock Ferry and Stockhouse, from thence through the low grounds of South Ease, and cross the White Wall to a point of division in Rodmill Tenantry, there to branch off in three directions; the N. W. branch to sall in with Kingston drain; the north branch to pass between the two Ries to bring down the cock-shot water, which will be useful for the cattle, and prevent its being particularly embanked; from thence through Lewes brooks below bridge, and under the river Ouse in a subterraneous tunnel, answerable to one of the old passages that cross the street east of Lewes

\* By fixing doors proper for that intent, this fluice may be made useful for procuring artificial scours at low water in dry seasons.

Bridge; from thence through the Malling brooks, and again croffing the river into Lewes brooks above bridge, from thence upland port brooks, skirting the river with a bank and drain (without following the minute windings) as far as the drainage is wanted to be carried, which, on the west side, I have supposed to be as far up as the iron-hole; for the sake of the brooks east of the river another tunnel will be necessary to convey their drainage across the Ouse a little above Mr. Kemp's, and thence skirting the river with bank and drain as on the east side, as far as the artiscial drainages are wanted, which I have supposed to be the Carp-Hole or Horse-shoe brook.

Returning now to the point of division, the N. E. branch is intended to cross the river Ouse by a subterraneous tunnel, and proceed directly to the pool in Ranscombe, from thence proceeding eastward to cross the boundary of Ranscombe, and after that skirting the river Glynde with a bank and drain on the north side till we are past the turn-pike-road, and the brooks grow broad and open on the south side the river; from this point the drain is to be pursued on the north side, supposed to Edley, for draining the great hoof, &c. crossing the Glynde from the said point, by a subterraneous tunnel, and in like manner carrying bank and drain on the south side; this will serve for a drainage of the Firle brooks, and what else on that side of the river may be surther necessary.

The Beddingham, Asom, and Itsord brooks are also to be drained by Inbterraneous tunnel under the river Glynde, to communicate its drainage with Ranscombe.

The carrying the drainage through the South Ease and Tarring brooks may possibly be objected to, as bringing the waters upon them; but as they lay higher than the rest, and the earth dug out of the drains forming, of course, a much more than sufficient barrier bank, they cannot possibly receive any prejudice, but, on the contrary, will barrier drainage rendered more effectual by draining into the new cuts proposed to pass through them.

J. SMEATON.

Austhorpe, 27th July, 1768.

[ 350 ]			
P. S. The general level, as taken the 18th and 19th of June, 17 to Lewes Bridge, the latter being the moon's quarter-day, was as follows:	б7, fro ws:	m the	lea
		Pt.	In.
Rise from the sea (at a slowing water) to the pier head at Newbaven, -	-	4	01
From the pier head to Sleeper's Pool,	-	1	81
From Sleeper's Pool to the top of the Broad Salts, below Piddinghoe, by estimation, -	-	0	10
From low water surface, at the top of the Broad Salts, to the water's surface in the we	A level		
near Sbine fluice,	-	- B	5
Rise from the surface of the west level water to the surface of ditto, at Leaves Bridge,	by esti-		
mation,	-	-	4
		13	4
N. B. On comparing the high water mark at the pier head at Newbowith the foregoing levels it appears, that the high water at the pier he level of the furface of the water at Lewes Bridge the same day 2 feet 2	ad was inches	abov	e the

ESTIMATE for Lewes Laughton Level, upon the principles of the first scheme.

GENERAL WORKS.			
To a sea-stuice of 40 feet water-way, containing three passages, two of 13 feet each, with	L.	5.	d.
pointing doors to seaward to keep out the tides, and ditto to the land, for holding up water			
for the navigation in dry seasons, and one passage of 14 feet, to be furnished with a double			
pair of gates pointing to seaward, in order not only to keep out the tides, but to form a			
navigable lock to let the vessels pass at all times; to be built with brick, with stone quoins			
and facings, the thresholds to be laid a feet below low water mark, in that part of the			
river opposite the sluice,	4000	0	0
To cutting a new river opposite Piddingboe, to be 27 feet bottom, and sloped in proportion of			
3 to 5, (that is 3 perpendicular to 5 horizontally) and being 9 1/2 feet deep, will be 59 feet			
at top, and which, for 4 furlongs 3 chains length, will contain 42,948 yards, at 5 d. includ-			
ing drainage,	894	15	C
To 7 to a acres of land for the cut and cover, the cover being supposed at half value, is			
reckoned at half quantity; the value per acre I do not pretend to judge of, but if, for the			
fake of estimation, it be reckoned at 40 l. an acre, this will come to, -	307	4	0
To a new cut from the turn of the river below White Wall, to the turn of the river above			
Stock Ferry, being of the same dimensions as the other, and 4,6 surlongs in length, will, at			
the same price, come to	017	2	9
	328		
To 8 22 acres of land, at the same price, cut and cover.	340		
In order to prevent the necessity of letting in the tides, for the sake of the navigation in dry			
feasons, and also to give the water a more free passage in its lowest state, it will be neces-			
fary to deepen the following shoals, viz. Dean shallow, Sound shallow, Bramble Bush		_	0
ditto, Snow ditto, Cliff ditto, and Tapfall ditto, these at 100% each, will come to	600		
General works,	7087	18	9
	-		

Parti-

Particular Works for the Levels west of the Ouse, below Lewes-Bridge, a sides above, on north of ditto.	nd on	bot	n.
To making new banks on the west side of the river, from the head of the new cut below White Wall, to the high land at Southover, being in length 28 surlongs, to be at a medium 24 seet seat, 6 seet top, and 6 seet high, the matter being taken out on one side, so as to	£.	J. 4	₹.
form a back drain, at 3 d.  To land to be converted into a drain, in order to make the bank, (the land being low, I	770	0	•
reckon no spoil of land by the cover of the bank,) this, for 28 furlongs length, will be 10,1 acres, which, if valued at 15 l. per acre, will come to	311	10	0
To making a new sluice of 6 seet clear water-way un the north side of White Wall, the threshold to be laid two seet lower than Shine sluice, to be built of brick, with stone			
To making a drain from the new fluice to join King flow fewer, to have a feet bottom, flopes	300	0	0
as 3 to 4, and, at a medium, 5 feet deep, this, for $7\frac{1}{2}$ furlongs, at $2\frac{1}{2}d$ . per yard, including drainage, is  To land to be cut for the said drain, the land being low, I reckon no damage for cover $2\frac{2}{10}$	120	6	3
acres, which if reckoned m 15 l. per acre,	33	0	a
the washing-place opposite St. John's, Bell Shallow, above Mr. Kemp's, Stoneham sheep-wash, and Hanjey Flats, at 501. each,	200	0	0
Particular expence of the west and north levels,	1574	16	3
Particular Works for Ranscombe Level, and Level on the Glynde, on the ea	st of th	e Oi	uje.
To embanking Ranfcombe, from the high lands at Walker's Hole, to furlongs, and up the river			
To embanking Ranfcombe, from the high lands at maintry			
Cala fame dimensions and price as before,	522	10	0
Glynde to Savale Bank, 9 furlongs, or the lance different to make the bank, at 15%	102		
To 6 106 acres of land, to be converted into a drain to make the bank, at 151.  To a new fluice at Ranfcombe of 4 feet clear water-way, the threshold to be laid = feet lower to a new fluice at Ranfcombe of 4 feet clear water-way, the former.	200	12	0
Glynde to Savale Bank, 9 furlongs, or the latte differential and part of the bank, at 151.  To 6 10 a ceres of land, to be converted into a drain to make the bank, at 151.  To a new fluice at Ranfcombe of 4 feet clear water-way, the threshold to be laid • feet lower than the threshold of the present sluice, to be built • the former,  than the threshold of the present sluice, to be built • the former,  To embanking of Ranfcombe • before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the Glynde, above Savale Bank, it will be necessary to take out a part of the earth from the	200	12	0
To 6 100 acres of land, to be converted into a drain to make the bank, at 151.  To 6 100 acres of land, to be converted into a drain to make the bank, at 151.  To a new fluice at Ranfcombe of 4 feet clear water-way, the threshold to be laid feet lower than the threshold of the present fluice, to be built the former, than the threshold of the present fluice, to be built the former, than the threshold of Ranfcombe before proposed, supposes the matter to be taken at the To embanking of Ranfcombe before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the Glynde, above Savale Bank, it will be necessary to take out a part of the earth from the Glynde, above Savale Bank, it will be necessary to take out a part of the earth from the river river Glynde, in order to dyke it out. The extra expense, therefore, in dyking out the river form its mouth to Savale Bank, and therewith in part making the bank alongside, Clynde, from its mouth to Savale Bank, and therewith in part making the bank alongside, as to make it I soot deeper than the present threshold of Ranfcombe sluice, may be set at	200	0	0
To 6 \$4 acres of land, to be converted into a drain to make the bank, at 151.  To 6 \$4 acres of land, to be converted into a drain to make the bank, at 151.  To a new fluice at Ranfcombe of 4 feet clear water-way, the threshold to be laid feet lower than the threshold of the present fluice, to be built the former, than the threshold of the present fluice, to be built the former, than the threshold of Ranfcombe before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the Glynde, above Swale Bank, it will be necessary to take out a part of the earth from the Glynde, in order to dyke it out. the extra expence, therefore, in dyking out the river river Glynde, from its mouth to Swale Bank, and therewith in part making the bank alongside, Clynde, from its mouth to Swale Bank, and therewith in part making the bank alongside, To dyking out and scouring the river Glynde, from Swale Bank to the west end of the Great To dyking out and scouring the river Glynde, from Swale Bank to the west end of the Great To dyking out and scouring a general out-fall to the eastern brooks, being in length 12 furlongs, Heof, for procuring a general out-fall to the eastern brooks, being in length 12 furlongs,	200	0	0
To 6 100 acres of land, to be converted into a drain to make the bank, at 151.  To 6 100 acres of land, to be converted into a drain to make the bank, at 151.  To a new fluice at Ranfcombe of 4 feet clear water-way, the threshold to be laid feet lower than the threshold of the present fluice, to be built the former, than the threshold of the present fluice, to be built the former, than the threshold of Ranfcombe before proposed, supposes the matter to be taken at the To embanking of Ranfcombe before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the Glynde, above Savale Bank, it will be necessary to take out a part of the earth from the Glynde, above Savale Bank, it will be necessary to take out a part of the earth from the river river Glynde, in order to dyke it out. The extra expense, therefore, in dyking out the river form its mouth to Savale Bank, and therewith in part making the bank alongside, Clynde, from its mouth to Savale Bank, and therewith in part making the bank alongside, as to make it I soot deeper than the present threshold of Ranfcombe sluice, may be set at	200	0	0

# I 352 1

### ABSTRACT.

General Works,  Particular expence of the west and north levels,  Particular works for Ranscombe, and levels upon the Glynde,	£. 7087 1574 1155	18 16 2	#
	9817	17	
Upon the above we may allow 10 per Cent. for unforeseen accidents, and contingent works not brought to account in the above, together with utensils and supervisal,	981	15	1
	10,799	12	-

SECOND ESTIMATE for Lewes Laughton Level, upon the principles of the second scheme.

# GENERAL WORKS.

GENERAL WORKS			
To the sea sluice at the tail of the main drain of 12 seet clear water-way, the threshold to be laid 1 foot below low water mark, with pointing doors to seaward, and draw gates to landward, for holding up water in dry seasons for the use of cattle, to be built with brick,	£	f	d.
with stone facings,  To the main drain, to be carried as per plan, through Tarring Tenantry to White Wall, to have a 12 feet bottom, slopes as 3 to 4, to be dug as deep as the sill of the sluice, that is at a medium $8\frac{1}{2}$ feet deep, the length being 15 surlongs, at $4\frac{1}{2}d$ . per yard, including	1200	•	ill .
drainage,  To putting a subterraneous tunnel across the river Ouse, in the reach between Stock Ferry and	1361	5	0
Stockbouse, of 12 feet water-way,  To continuing the main drain from White Wall to the point of division, bottom and slopes as	1000		0
before, the depth being about 6 feet, and 5 ½ furlongs length, at 4 d. including drainage,  To purchase of lands from the out-fall sluice to White Wall, cut and damage of cover at 66  feet broad, and 15 surlongs length, will contain 15 acres, which, if estimated as before at	268	17	7
40 l. will come to	600	O SEE	0
low, I reckon no damage of cover) at 2/ feet of cauti, and 1/2 factors are 1/2 feet of cauti, and 1/2 feet of ca	34	5	0
General works,	4464	7	7

## ESTIMATE of works to be done in the west level.

EDITIVITED OF MOURT OF GOING IN THE MELE ICACK			
	£. 1.	2.	
To continuing the drain from the point of division, up to meet King ston sewer, upon a 6 feet	~		
To continuing the drain from and at a madium of feet deen this for 2 4 forloage at 2 1 d.			
the batters 3 to 4, and at a mendant 5 reet deep, this for 2,4 thinburgs, at 4 1 mm	38 10	0	
i factualing drainage, coines to			
The same King Non Lewer Continuing and Allica, 41 LVD	\$ 5	Q.	
1			
14 I AND SA PROPERTY STATE STATES AND SAME AND			
be a medium 24 leet leat, 6 seet top, and 5 se	825 -	0	
be a medium 24 feet feat, o feet top, and o feet lags, as jury and o feet lags, as jury and j	162		
To 10 to acres of land, converted into a dram for forming the more with the bank drain,  To cutting a new north fewer, from the point of division to its junction with the bank drain,  To cutting a new north fewer, from the point of division to its junction with the bank drain,			
To cutting a new north fewer, from the point of divinou to its junction of the feet mean depth, containing it for- to have a 6 feet bottom, hatters is 3 to 4, and five feet mean depth, containing it for-			
to have a 6 feet bottom, natters in 3 to 4, and not to the state of the longs in length; this at 2 ½ d. per yard, including drainage, comes to to longs in length; this at 2½ d. per yard, including drainage, comes to		2	
longs in length, this me spoil of cover, containing 3 700 acres, at 15 l. per acre,	48 6	5 0	
longs in length; this at $2\frac{1}{2}d$ . per yard, including diamage, containing 3 $\frac{23}{106}$ acres, at 15 l, per acre,			
	T255 10	0 2	
Particular charge of the west level.			
•			
Estimate for the north Brooks above Lewes Bridge.			
To making a 5 feet tunnel across the river, at the head of Lewes brooks,	600	0 0	
To making a 5 feet tunnel across the river, at the real and therewith forming a bank,			
To making a 5 feet tunnel across the river, at the head of Letter with forming a bank,  To making a sewer of 6 feet bottom, with slopes = 3 to 4, and therewith forming a bank,  by laying the earth on one side, at a medium sect deep, will make a bank 20 feet seat,  by laying the earth on one side, at a medium sect deep, will make a bank 20 feet seat,  by laying the earth on one side, at a medium sect deep, will make a bank 20 feet seat,			
by laying the earth on one fide, at a medium   feet deep, with make a horking included, for 30			
by laying the earth on one fide, at a medium I feet deep, with induced, for 30 5 feet top, and 5 feet high; this at $z \frac{1}{2}d$ , per yard, cutting and banking included, for 30 5 feet top, and 5 feet high; this at $z \frac{1}{2}d$ , per yard, cutting and banking included, for 30			
5 feet top, and 5 feet high; this at z 1/2 d. per yard, cutting and bankers, to the iron furlongs, from the river opposite the head of Lewes brooks, below bridge, to the iron	481	5 9	ą
furlongs, from the firm farm.			
hole at the head of Hanfey farm,  To land for the above fewer, containing 8 to acres, at 15 l. an acre, no spoil allowed for	132	0	a
To land for the above lewer, containing of	0.50	0	a
house	1		
banks,  To probable extra expences in the cut passing the street east side of Leaves Bridge,  To probable extra expences in the cut passing the street east side of Leaves brooks, above bridge,	500	0	ď
To probable extra expences in the cut passing the street east inde of Brooks, above bridge,  To a 5 feet tunnel to pass the river, from Malling brooks to Lewes brooks, above bridge from			
To a 5 feet tulinet to pass the river above Mr. KEMP's, to communicate	400	0	Q
To a 5 feet tunnel to pass the river above Mr. Kemp's, to communicate the drainage from To a 3 feet tunnel to pass the river above Mr. Kemp's, to communicate the drainage from			
the east fide,	336	17	6
To a 3 feet tunner to paid to the faid tunnel on the east, to the Horse-Shee brooks, of the east fide,  To making a bank and sewer from the said tunnel on the east, to the Horse-Shee brooks, of	92	5	q
1 C - I work HARCON IN LINE PARTIES			
To land for the above drain 0 100	2792	7	6
North brooks	-19-		
C. D Comphe.			
Estimate for the drainage of Ranscombe.			
The second of th			
and a seint of division to Ranfcombe pool, to have a selongs, at 2 and			
To cutting a main drain, from the point of the length being & furtongs, and a feet deep, the length being	136	7	
To cutting a main drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain, from the point of division to Ranscambe pool, to have a drain drain, from the point of division to Ranscambe pool, to have a drain drain, from the point of division to Ranscambe pool, to have a drain drain drain, from the point of division to Ranscambe pool, to have a drain	- 37	7	
mer word.			_
To land for the above cut, containing 2 100 acres, at 15 !.  Carried forward	. 173	14	
To land for the above cut, contained a Carried forward	13		
Z z			
Wor. I.			

₩ol. I.

Abstract of the drainage of Lewes Laughton Level, by the second method.

		L.	1.	m²
Brought forward	d,	173	14	
To making a 6 feet tunnel across the river Ouse,	op, and 6 feet	800	0	_
high; this for 19 furlongs, at 3 d. per yard, back drains included, comes to		522	10	a
To 6,84 acres of land, occupied by the drain from whence the bank is to be tal	ken, at 15%	102	1 2	0
Particular charge for Ranjcombe,	- £.	1598		
Charge of draining the east brooks, or brooks east of Ranscomb dingbam, Asem, and Itsord.	be, as also th	ofe of	f Be	d-
To cutting a drain, from Ranscombe pool to the east extremity of Ranscombe, to bottom, slopes as 3 to 4, and at a medium 5 feet deep; this, for 6 furlouge,				
yard, will come to		96	5	0
To land for the above 1 76 acres, at 15%		26	8	0
To cutting a drain of 6 feet bottom, with slopes as 3 to 4, and therewith for against the river Glynde, by laying the earth on one side, at a medium 5 st make a bank of 20 feet seat, 5 feet top, and 5 feet high; this, for 18 surlo	feet deep, will			
head of Swal: Bank, through the Great Hoof to Horfe Brook, at 2 1 d. per yard,		336	3	q
To land for the above drain $5\frac{27}{100}$ , at 15%		79		0
cate the drainage of Firle brooks with the former drain on the north side,		150	0	166
To embanking the Firle brooks against the river Glynde, opposite the Great Hoof, a forming a drain, supposed of the same dimensions as the north side; this so				
will come to,		144	7	6
To land for ditto 2 64 acres, at 151.		39	12	G
To putting a tunnel across the river Glynde, in order to drain Beddingham broo	oks, of 3 feet			
water-way,		200	Q	- 53
To embanking those brooks against the river Glynde, and thereby making a drain	in behind the			
bank, which is to have a 24 feet seat, 6 feet top, and 6 seet high; this, at 3	3 d. per yard,			
for 7 furlongs, will come to		192	10	
To land for the above drain 2 52 acres, at 15 l.		37	16	0
To embanking Asem and Itsord brooks, against the river Ouse, and thereby ma behind the bank to communicate with that of Beddingham, being in length				
which being of dimensions and price as Beddingbam, will come to -		385	ill	0
To land for the above drain 5 760 acres, at 15%.		75	12	0
Particular charge of the brooks upon the Glynde, exclusive of Ranscombe,		1762	13	6.

	£.	ž,	d.
The general works for bringing the drainage to the point of division in the west level,	4464	7	7
	1255	10	2
paimate for the north brooks above Leaves Bridge,	2792	7	6
for the drainage of Kanfrombe,	1598	16	1
of draining the brooks call of Kanjeombe, in allo those of Beadingham, Ajem, and Hjord,	1762	13	6
then the above we may allow 10 per cent, for unforeleen accidents and contingent works			
	1187	7	6
	13061	2	4
			_
and a Tuly and 17/2		-	
Austhorpe, July 27, 1768			

J. SMEATON.

#### A SHIP's PUMP.

DESCRIPTION of a Ship's Pump, defigned by John Smeaton, Engineer.

A Pump of this construction was designed in the year 1765 by Mr. SMEATON, and executed from his directions by Mess. Hurrey and Co. at Howden Dock, upon the river Tyne, the latter end of the same year, which meeting with the approbation of the master of the ship on board which it was first fixed, who reported that it had actually saved the ship, some others have since been made nearly similar by the same company, but the superior expence has hitherto prevented so great a demand as might have been expected. In the present design, in which the whole has been carefully reconsidered, I have not rigidly adhered to the particularities of the first construction, but altered such smaller matters as convenience seemed to suggest.

Besides the advantages that were expected to accrue above the common form from better mechanism and proportion of the parts, the following was in view: the common ship's pump in general delivers its water upon the main deck, which, according to the largeness and construction of the ship, is 4, 5, and 6 feet above the load water line, at the same time that the load water line is not above from 14 to 18 feet above the ship's bottom; it therefore appears, that the ordinary pumps list the water from \( \frac{1}{4} \) to \( \frac{1}{4} \) higher than the level at which the water might be delivered, and thereby require \( \frac{1}{4} \) or \( \frac{1}{4} \) in case the water was delivered at or just above the water line for this purpose.

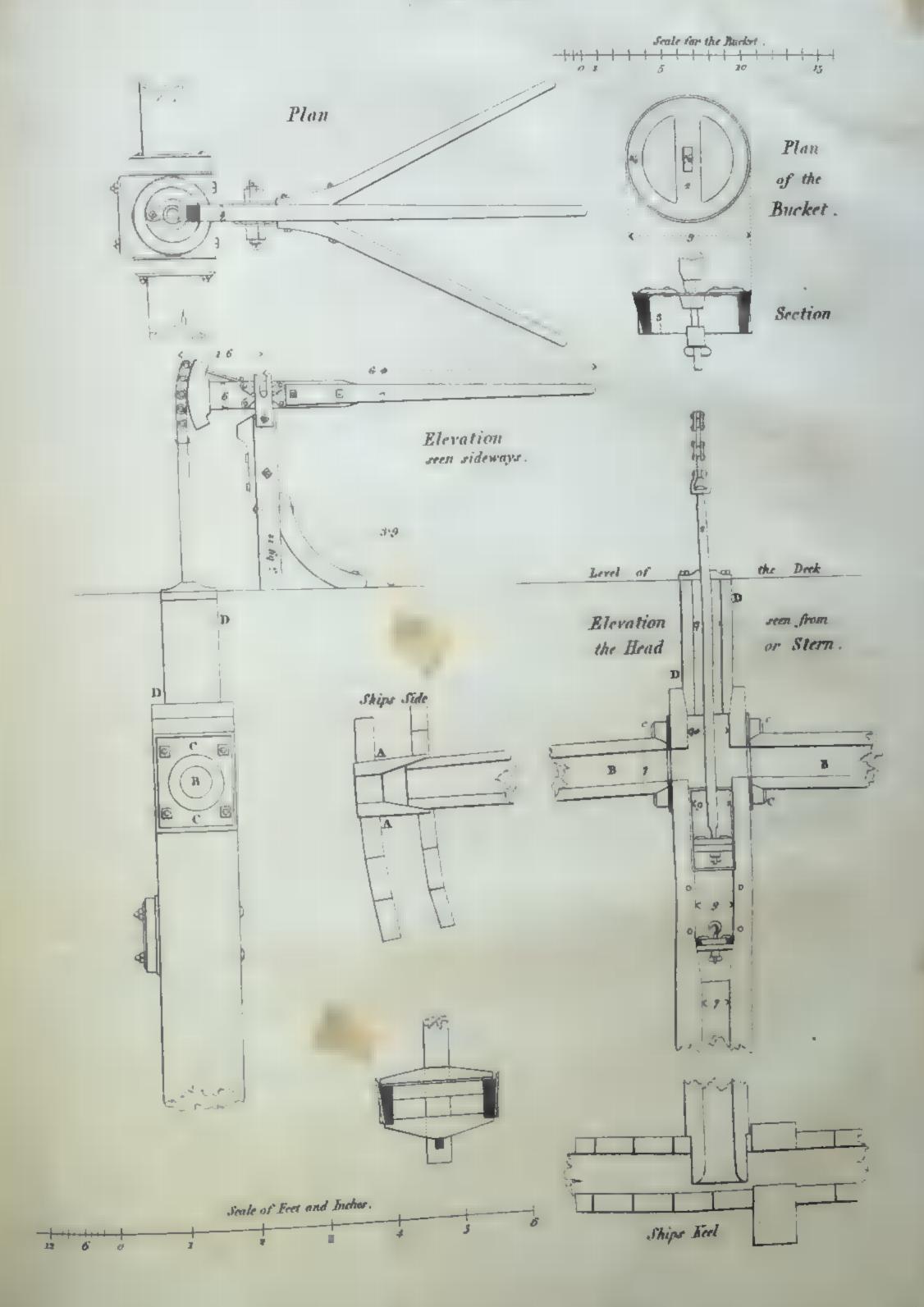
A A, boxes let in through the ship's side, and caulked just above the load water

B B are side pipes, jointed with the boxes, and with

8 1 1 h

CC, strong planks bolted against the sides of the pump, in order that the side pipes may be got out and in without disturbance to the pump.

DD is a stand-pipe, to be carried up to the main deck, or as high as is thought necessary, that when the seas rise above the orifices, or the ship in distress, should be under her load water line, that the water may not revert and run into the ship: and here



In Exer delin

will no ways interrupt the action of the pump; for whenever the water in the standpipe rises above the level of the water without, the pressure of the column in the standpipe will cause it to make its way through the side pipes; so that in this case no level will be lost, and though the pump is at rest, no water can revert down the pump, because there are the valves of both bucket and fixed box to prevent it.

The present design is adapted to be worked at the height of 22 sect by sour men, who working at a moderate rate, so as to hold it an hour, will in that time deliver 20 tons. This is upon a supposition of raising the water to the usual height; but is, by the application of the maxims above described, this perpendicular is shortened to 16 or 17 feet, then will the same delivery nearly be made by three men, or proportionably more by sour men, that is, as 17:22:120:26 tons at 17 feet; but in this case, the distance of the center of the lever or brake must be lengthened from 1 foot 6 inches to 1 foot 11 inches 3, and the barrel must be lengthened 4 inches.

According as the design is drawn, viz for a perpendicular of 22 seet by sour men, they are supposed to make no more in 25 strokes per minute, moving the pump-rode up and down at each stroke. This will be much better than to make shorter strokes and quicker, as they usually do; in this case their hands will move up and down about 4 seet 6 inches, and the same number of strokes, scope, and pressure at the hand will be sufficient for the reduced perpendicular, but then the stroke of the pump-rode will be  $17\frac{1}{4}$  inches.

With respect to the mechanism, I believe it will appear sufficiently plain by the defigns, which are drawn true to a scale; but it may be necessary to remark, that the working-barrel is to be of brass, and very truly bored, the bucket and fixed box of the working-barrel is to be of brass, and very truly bored, the bucket and fixed box of the same construction as those used in the steam-engines, and the pump-rod is to be made fame construction as those used in the figures, not by way of strength, but by way of weight; of the bulk represented in the figures, not by way of strength, but by way of weight; that when the brake is lifted up the pump-rod may readily descend by its own weight; and it is to be noted, that if the weight arising from the dimensions specified does not and it is to be noted, that if the weight arising from the dimensions specified does not leathered, or the valves too heavy.

It is to be observed, that the foot of the pump is to be let through the cieling betwixt two of the floor timbers, and not to touch the bottom or outside planking within 2½ inches, and that the lower end be rounded trumpet fashion. I entirely object to the pump's standing upon its lower extremity, with holes bored to let in the water.

N. B.

N. B. If the foot stands close to one or both timbers, there ought to be left 3 inches between the bottom and the planking.

In case the pump is made to the 22 seet height the stand-pipe will then become unnecessary; and therefore to allow a proper length and weight to the pump-rod it will be proper to let down the working-barrel door and box lower down in the tree. The quantity must be assigned by the convenience of coming at the door; but the working-barrel had better not be above 16 or 17 seet above the bottom, if it can be avoided.

The four men are supposed to stand one on each side the middle stem of the brake, and one on each outside of the branches, and every quarter of an hour they will find an eastment by changing hands, which is done by changing places.

This pump may be worked by fix men, but not so as to produce a greater quantity in proportion to four; it may also by three, but then they must change every quarter of an hour.

It may be made also to work double, in which case eight men may be employed with advantage; but as I imagine two independent pumps will be better adapted to ships use, that if one be out of order, or happen an accident, the other may be serviceable, it is for this reason I have not given a design for a double pump.

I suppose it scarce needful to say, that it would proper that a bit of the cieling should be made to lift up near the pump's foot, that a man may occasionally get in his arm to clear away any chips, sand, dirt or other matter that may happen to be drawn thither.

Austhorpe, 9th August, 1768.

J. SMEATON.

#### CARRON FURNACE.

The REPORT of JOHN SMEATON, Engineer, concerning the Improvements of the Blast at the furnace at Carron, No. 4.

HAVING maturely considered the easiest and most essectual way of altering the blast No. 4, so as to perform its business equally with No. 1, I recommend the following alterations, yet, without a total change, which is not the present object, the company will be obliged to submit to its using more water than No. 1, though, in this respect, they will find it greatly improved beyond its present state.

I would advise that the water-wheel and the three cylinders, with their respective beams, remain as they now do, as also the frame that holds the crank, but to add a fourth cylinder abreast of the other three, on the outside or surthest off from the water-wheel, as also a fourth beam abreast of the other; the sourth cylinder to be of the same size, and in all respects fitted up similar to the other three. On this occasion it will be necessary to cast move crank with four as, making right angles with one another, and at distances answerable to the four beams, and having the same sweep as at present. I am not perfectly clear whether there may be room enough between the present outmost cylinder and the wall to place the new one, but if not, the wall must be cut away to make room for it; with respect to the beam, it is no matter if it works very near the wall. Another couple or frame must be added for the crank like the present, and like the present the fourth neck may work in the air without an outward support. The receiver or air vessel will probably want recasting, to receive mounts air-pipe from the fourth cylinder, unless the workmen can contrive to cut a hole into it, and by proper straps to confine the additional pipe thereto.

As I observed a great deal of friction in the rods passing the collars in the top of the oylinder, and yet lost a great deal of air, I mentioned last summer a method of leather-oylinder, as well as those of the fire-engine, in a different way, whereby they would ing them, as well as those of the fire-engine, in a different way, whereby they would not only be rendered air-tight the friction in a great measure avoided; and, that this method may be properly and successfully applied, I inclose a drawing, which method I method may be applied not, only to the new cylinder but to the three old ones, which may advise to be applied not, only to the new cylinder but to the three old ones, which may be done by cutting off the present necks, and drilling holes for the bolts.

DESCRIPTION of the Collar of Leather to be applied to the Blowing-machine at Carron, No. 4.

A B represents a portion of the cylindrical rods that work though the collar of leather.

CD is a portion of the section of the great plate that covers the top of the cylinders.

EF is a fection of a cylindrical piece of wood, having a cylindrical hole through the middle, through which the rod may slide freely, but with as little shake as possible, which is to be made of beech, crab-tree, yew, or fome hard or tough wood that will wear well with iron.

abc abc shews the section of the leather by which the hole is made air-tight, and is like an hat with the top of the crown cut out.

GHIK GHIK is a fection of a cylindrical box for holding the cylindrical piece of wood, with proper flanches, by which the box is screwed down to the cover CD, and by which the plate, of which L M is the section, is screwed down so as to hold fast.

NO is the section of a piece of leather for securing the joint betwixt the box and the cover.

It is obvious from the figure, that no part of the cylindrical rod is intended to touch the ironwork nor the leather NO, but that it is to be kept steady by the wooden cylinder, and the joint rendered air-tight by the pliable cylinder of leather be be, which, as well as the wood, are to be changed whenever they are found to fail.

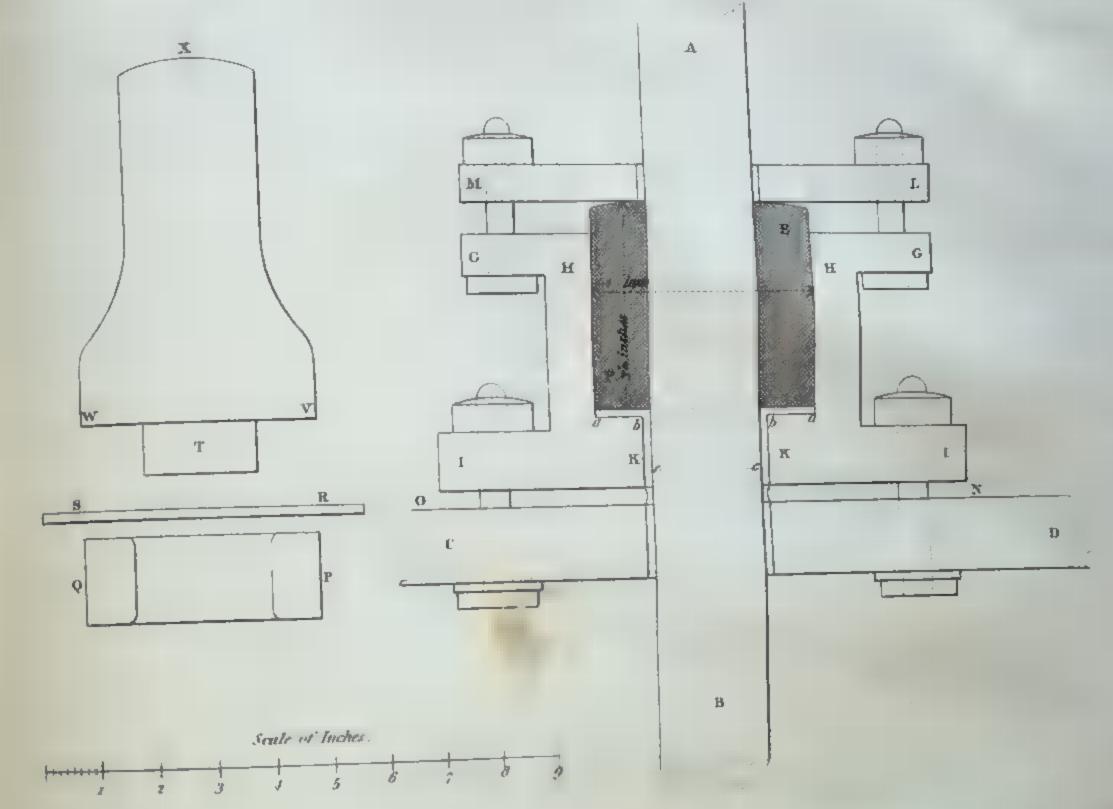
The method of making those leathers is as follows:

P Q represents the section of a cylindrical iron ring, whose external diameter is equal to that of the wood CD, and whose internal diameter is about + of an inch larger than the diameter of the cylindrical iron rod A B.

RS is the section of a flat round piece of leather of about 1 of an inch thick, being of the thickest fort of leather used for the upper leathers of shoes.

TYWX

DESIGN for a COLLAR of LEATHERS, for the Blowing Engine Nº 4, at Carron.



Vol. L.p. 403. DESIGN for a NOSE PIPE for CARRON. 7 Inches Diami. I - 6 Inches

TVWX is a piece of hard wood, turned to the shape here represented, whereof the part T is of the same diameter as the cylindrical rod AB and VW, to the same diameter as the wood EF; then having cut the piece of leather to about an inch more in diameter than VW, with a mallet sticking upon the head of the piece of wood at X, the leather will be forced into the iron ring, and form the shape of an hat, and with a knife cutting off the superfluities even with the outside of the wood VW, it will then be of a size proper for use; after staying some little time, release it, and with sharp narrow-bladed knife cut out the crown even with the inside of the cylindrical part of the leather, and by holding the blade of the knife parallel with the axis of the cylinder, it will give it the shape abc abc.

The leather will be rendered more compliable, if need be, by being first wet, and will keep its shape better if suffered to dry in a thin hoop, whose inside is the same as the inside of the ring PQ; if it cannot be made without puckering, it is a sign that the part T is too prominent, for even  $\frac{1}{2}$  an inch of turn down will answer the purpose; dintle leather wetted is also more compliable than the common tanned.

It is to be observed, that the rods be drawfiled very smooth, and first of all worked with a mixture of soft grease and powder of black lead, and asterwards black lead simply.

It will also be of further advantage, in respect to the saving of water, to lay the water about three buckets higher upon the wheel, according to the method first proposed for No. 1.

J. SMEATON.

Austhorpe, February 11, 1769.

Answer to Que by Mess. GRIEVE and BENSON.

Carron, July 10, 1769.

Mr. GASCOIGNE having shewn me Mr. SMEATON's letter to-day, in which there is the following query, viz.

"Mr. Grieve informed me, that at the rate I saw No. 4 a-going, viz. 18 cylinders per minute, that she did 30 baskets per day: query, what is her common rate of blowing,

A a a

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ing, that is, how many cylinders in common with a full head, and how many baskets is then done?"

To which I answer, that 18 cylinders per minute is the usual rate of blowing at No. 4; that she blows down from 30 to 35 charges per day; she is not now allowed to go more than 18 cylinders a minute, which is performed at the lower gate at all times, and with the upper gate when the pool is very full. Some time ago both gates were used, even then she never went more than 21 or 22 cylinders per minute, nor more than between 30 and 35 charges per day, yet I have known her drive as many as 45 charges per day; fuch is the uncertainty of founding on the number of charges as the basis of a calculation.

He also informed me, that No. 3 made 15 cylinders per minute with a gate, and 18cylinders with both; query, how many baskets respectively?

To this I reply, that No. 3, with a full head, does make these cylinders; at this furnace we always blow with both gates, and therefore I cannot say how many charges she may run at 15 cylinders per minute; but at 18 she blows down from 25 to 29 charges per day, and if the water in the pool be 2 feet or 30 inches lower than full head, this No. 3 furnace will not drive above 15 or 16 charges per day.

Mr. SMEATON will please to advert, that a charge consists of several baskets of mine, coal, and lime-stone, which is put into the furnace when the materials are sunk in her to a certain depth; now this charge confifts sometimes of more or less baskets than at other times, just as the working of the furnace requires it; and it must likewife be observed, that the quality of the materials has great influence on the driving of the furnace.

JOHN GRIEVE.

When No. 1 blows 25 cylinders per minute, she will make 28 baskets per day.

When No. 2 blows 34 bellows per minute, she will make 20 baskets per day.

J. BENSON.

Mr. BENSON'S Answers to Mr. SMEATON'S Queries of the 11th, as far they respect No. 1 and 2.

Carron, July 12, 1769.

IN the first place Mr. SMEATON will please to observe, that the coals and lime-stones used in each surnace are all of the same qualities, and nearly the same quantities; the difference is not worth notice.

Query 1st. Answer. The mines used in No. 1 and 4 are quite different qualities, so can only say what difference there is in the weights of the mine used to a charge; No. 1 charge of mine is about it to it heavier than No. 4; when No. 1 is running 28, and No. 4, 30 to 35 charges per day, supposing both surnaces of the same shape, but they are not, No. 1 blast is more repelled than No. 4.

Query 2d. Answer. The materials of No. 1 and 2 are much the same; the mine of No. 1 charge weighs about 1/2 heavier than No. 2; this difference arises chiefly from the shapes of the furnaces, and not from the blast.

Query 3d. Answer. The quality of the iron in No. 1 may be as good when she runs 28 charges per day, as when she runs 18 and 23, provided she be working what we call clean natural mines, or mines not possessed of poisonous matters; but the quality of the iron depends upon that, and the quantity of mine used to a charge.

Query 4th. Answer. I never wrought No. 2 at 10 to 12 charges per day; but was that the case, she would take a double set of men to work her, and the iron would be so cold for want of its mother cinder, which cinder can only be produced in a blast furnace by a proper quantity of blaft, it would be of no service but for pigs, and scarcely would run out of the hearth even into them.

JOHN BENSON.

Mr. GRIEVE'S Answers to Mr. SMEATON'S six Queries, dated the 11th instant, as far as they respect No. 3 and 4. B. Furnaces.

Carron, July 12, 1769.

TO Query 1st. The coal and limestone used to a charge is much the same in all the No. 1 furnaces. Aaa2

No 1. carries commonly  $\frac{1}{12}$  or  $\frac{1}{13}$  part of more mine to a charge than No. 4. but it must be observed that the quality of the mines used at No. 1. and No. 4. are always different, and to come at the ability of each, they should be loaded with equal materials.

To Query 2d. I reckon No. 3 carries is or in part more mine than No. 4; but this is as uncertain as the answer to query 1st, on account they are never loaded with the same fort of mine.

To Query 5th. With the same materials, I believe, No. 1 and No. 4 will make. nearly the same quality of iron, yet there may be a difference in savour of No. 1, on account of her drier situation, and her better make.

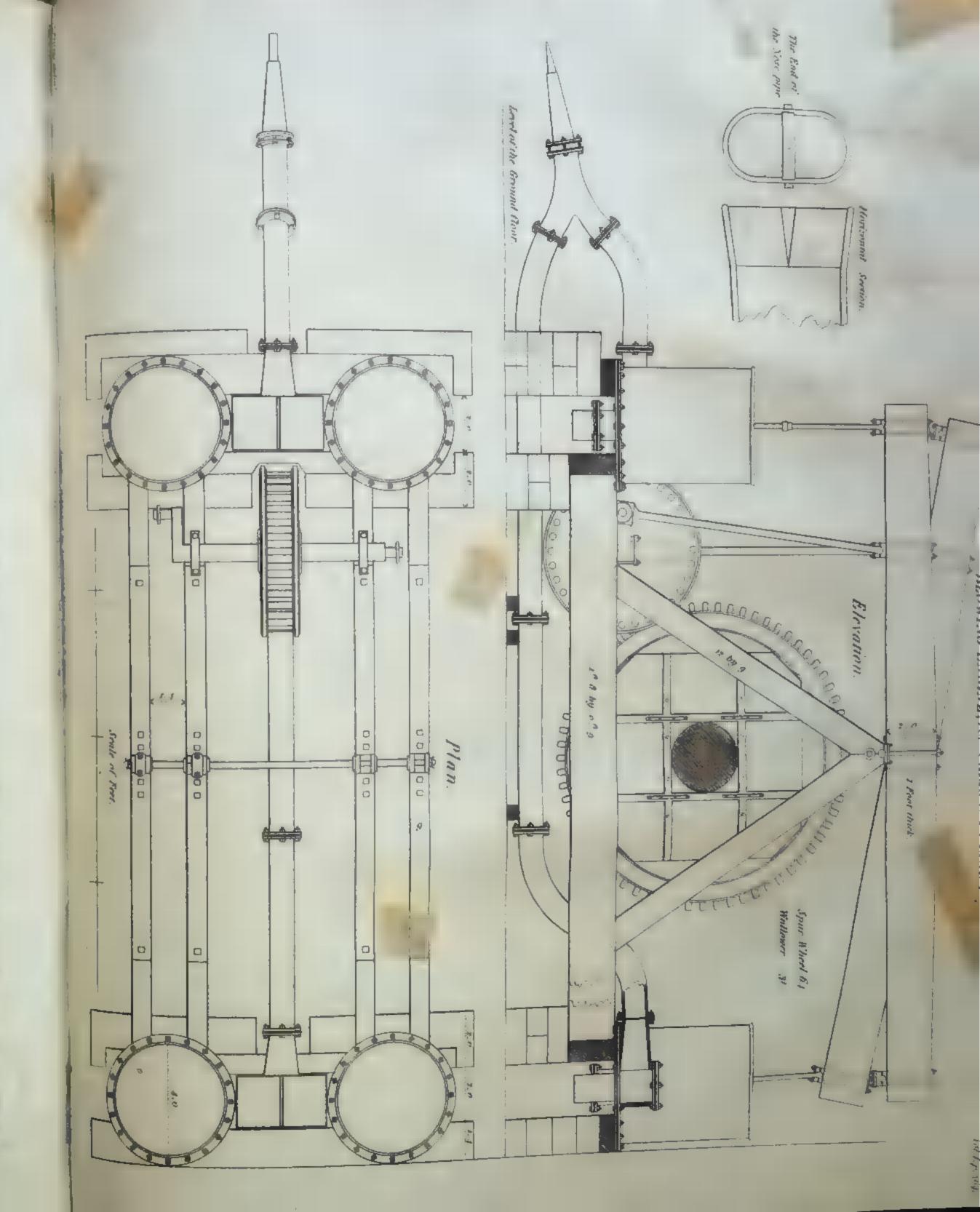
To Query 6th. This depends entirely upon the nature of the materials; No. 3, when the drives 25 to 29 charges a day, will make as good iron as when the drives only 15 or 16 charges a day, provided, in both cales, the be working what we call wholesome mines; but if the materials are endued with any pernicious qualities, every furnace will make better iron by working than fast: The reason is obvious, by driving flow the materials remain longer in the body of the furnace, and so have more time to throw out their sulphurs, or the heterogeneous matter, with which they abound, escapes by sublimation or attraction, which hard driving would carry down with and poison the iron.

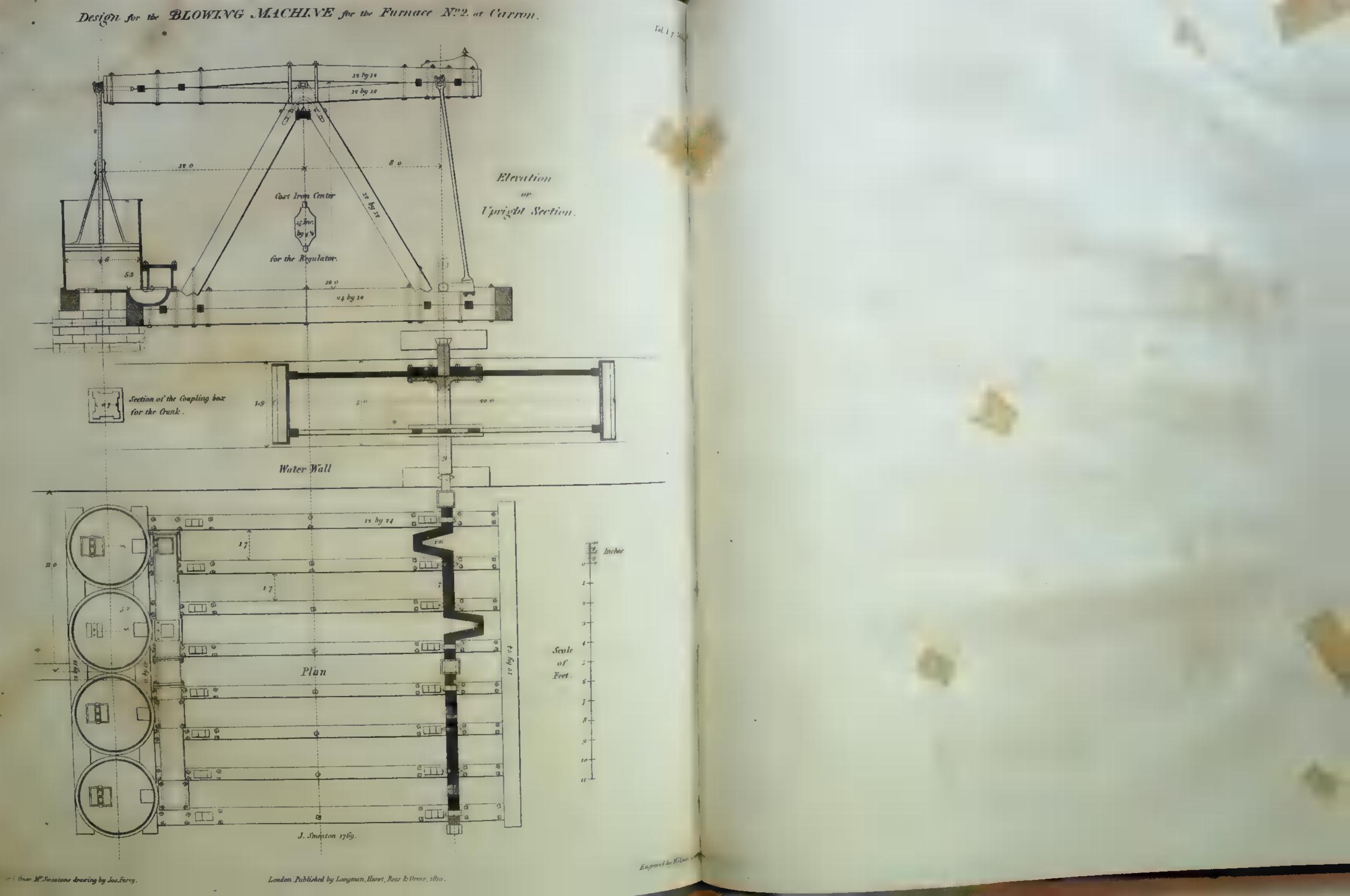
JOHN GRIEVE.

EXPLANATION for the Defign of the Blast Machine for the Furnace No. 2, at Carron.

AS in this machine I have the advantage of ordering the water wheel, which I judge best to be over-shot, this circumstance reduces its height so much, that, by a small enlargement of the cylinders, it can be allowed to go at such a speed as to do without geer, which however well they have answered in No. 1, where they were necessary, yet, where the same proportions in the movements can be accomplished without geer, are more properly avoided.

I have also chose, instead of making two regulator beams working a cylinder at each end, as in No. 1, to make four beams or great levers with cylinders at one end only, by this means, the strain of the crank always laying downwards, and bearing upon its brasses





J. Farey del! Designed by J Surcator 18 10/1/11/11 Beaugn for the WATER WHEELS. Wheel 18! so flouts. diameter. for the BORING MILL. at chrive. The outside streets both of & Seen were to be jointed with Coment . " I want The Rais the inside with good Morar rise. I a the are of fast fron. forge scales or Vincen

brasses the same way as the water-wheel, will work more easy and pleasant, and be less liable to get a shake, and be out of order by continuance of wear: The whole, therefore, of the motions being performed with more ease and simplicity than No. 1, I expect it to be subject to less attention and repairs, and that it will not require above \$ of the water to work it, taken by No. 1.

There will be more timber in the framing, but as it will be nothing but common fir timber, I apprehend this will be no object, and this will be more than faved in the water-wheel and axis, the spurn-wheel, and pinion.

No. 1 is a design for the upright of the water-wheel; it is here shewn to be of 20 feet diameter, but as, on my last view at Carron, I understand that the wheel No. 2 lays lower than the rest, and is sometimes affected by tail water, when Stenbouse milldam is full, a circumstance I was not before apprised of; in order to avoid that, it may, perhaps, be necessary to reduce the diameter of the new wheel from 20 feet to 19 feet 6 inches; but, yet, if Stenhouse mill-dam never throws above 3 inches dead water upon the bottom of the present wheel, then the new wheel may be laid as low as the present wheel, because that quantity of dead water, supposing the tail water-course from the wheel be open and free, will be of no rejudice to the going of the new wheel.

The reduction of the water-wheel to 19 feet 6 inches is, again, only upon a supposition that the pond is subject to be reduced I foot 9 inches below head, as I saw it the 7th instant; but if it is never suffered to go above I foot below head, as advised in my report of this day, or, at most, 14 or 15 inches, then the water wheel may be of its full fize, though it should be obliged to be raised at the bottom from 3 to 6 inches, to fufficiently clear the tail water.

The elevation here given is supposed to be of the outward front, but as I find the tail water goes off the centrary way to what is here shewn, and will require a different kind of penstock, for which I will send a particular design when I recuir to Eugland, it will be proper to lay a sweet of the breast of this wheel, to fit it as close as possible, a quarter round, or only ; of the circle as is found but it may either embrace most convenient in the execution; the two different ways are shewn according to the letters ABC and ADE.

The width of the wheel is supposed to be as great as the conduit will allow, as it will work steady like No. 1, no allowance need be made for shake.

Designed by J. Smeaton 1770.

J. Farey del!

Enseated by Adams

No. 2 is a plan of the whole machine, and an elevation of one of the truss frames and beams, with a section of one of the cylinders; upon which it is only necessary to observe, that as the method of framing the truis-frames are the same as No. 1, whatever difference there is in the disposition, will be sufficiently obvious from the draught.

It is, however, to be observed, that as, for the ease of casting, I have supposed the crank to be cast in two pieces, particular notice is taken that one of the heads be set a small matter atwist, with the arms of the crank, that when the whole crank comes to a bearing in the box that couples them together, the arms of the first half of the crank may make a perfect right angle with the arms of the second, otherwise if this circumstance is not attended to, the clearance necessary to get the box entered upon the two heads, will produce a shake, that when the whole comes to a bearing, the arms of the two halves of the crank will not stand square to each other, which will produce an inequality in the blaft.

The crank end of the regulator beam or lever has a piece of cast iron A, which is to be made of such a weight as to overhaul the piston, which, for the sake of lightness in this machine, is to be made of wood,, or as light of iron as it can be properly cast; the pistons, however, are to be leathered, as in No. 1; the proposed use of the weight at A overhauling the piston, is to prevent the crank-rod from changing its bearings upon the crank neck, for, by always bearing downwards, it will be no matter whether the neck-collars be tight or not, so that the only collars that will be needed to be kept tight, (which they very eafily may, having but little motion,) are the tops of the crank and piston rods, and the center gudgeon of the levers.

B is a provisionary flanch, which is here shewn to be mute; the opening to be about 6 inches diameter in the clear, and the use is, that in case a persect equality in the blast should be afterwards found to be preferable to all others, as I am at prefent much inclined to suppose, from hence there may be made a communication to an air receiver or vessel, which will fully effect that purpose.

J. SMEATON.

Kerse House, July 31, 1769.

#### The WATER at CARRON.

The REPORT of JOHN SMEATON, Engineer, concerning the quantity and disposition of the water at Carron, from a view taken thereof the 7th of July, 1769.

A S the several blast surnaces at Carron are of different dimensions, work upon different kinds of ore, and take different quantities thereof at a charge, the wheels take their water at different heights, and, at the time of this view, the pond from which they were ful plied was so low, that the head of water upon each wheel was a good deal uncertain in the different penstocks; it is not to be expected that any very accurate conclusion can be drawn by way of comparison of the several machines, in regard to their powers of reducing the ores or mine into metal; yet, in attempting the comparison in the best way I am able, it appears to me that several matters offer themselves which. feem worthy of serious attention from the Company.

Amidst the uncertainties above mentioned, it seems impossible to fix upon any absolute criterion or common measure to which they can all be reduced. The quantity of metal produced from the furnace seems improper, because the poorest ore (I must presume) takes most labour of the surnace, and yields the least iron; the different quantity of air that each machine throws into its respective furnace appears also equally unfit, because, if we are to judge by this alone, it will appear that the machine Nor 4 will, with an equal supply of water, throw out more air in a minute than No. 1; and this will also hold with No. 3, and therefore we must conclude that the machine No. 1 is inferior to No. 4, and also to No. 3. A conclusion which I suppose must. be rejected from all experience hitherto had, and consequently the premises from which. it is drawn.

It remains therefore that the number of charges, as they do not much differ in weight, which each furnace can work off in a given time, relative to a given quantity of water, is the only handle we can at present lay hold of, and is, as I perceive, the same by which the managers and workmen reckon; and though, on the account before mentioned, it. may not be very exact as common measure, yet I find the differences of the effects of the furnaces relative to a given quantity of water are so very remarkable, that though our conclusion formed from thence will be short of perfect accuracy, yet they may enable us to adopt a better distribution of the water than at present.

The distribution and effects of the water on the day of view was as follows:

		Strokes per minute.	Charges per d	ay. Cube fee	et of water expended per minute.
e N	lo. I.	19	23	267	
Table 1.	2.	28	. 18	555	
Table 1.	4.	16₺	30	780	
	To	tal charges per day	71	with 1602	cube feet of water per minute,

N. B. At this time No. 3 was standing still.

When all the furnaces have a full head and supply of water, the number of strokes of the cylinders and bellows per minute, relative to the number of charges per day, as per information of Messes. Benson and Grieve, are in the sollowing table; and comparing the several heads of water and apertures that these must obtain with the present, the expense of water relative to those strokes and charges will also be as therein specified.

		Strokes per minute.	Charges per day.	Cube feet of water.
	No. 1.	25	28	481
in 1.4	2.	34	20.	761
Table 2.	3.	18	27	1362
Table 2.	4	18	32 -	852
			1071	3456
			-0/2	3-7-

Now, comparing the respective numbers in the second table with those of the first, it appears, that the quantity of water expended to drive an increased number of charges, greatly exceeds the proportion in which the number of charges increase; for taking the totals, to advance the charges from 71 to  $107\frac{1}{2}$ , that is nearly as 2 to 3, the water must be increased from 1602 to 3456, that is more than in the proportion of 2 to 4. Again, in the surnace No. 1, to advance the charges from 23 to 28, the water must be almost doubled, and the disproportion greater or less is observable in all the rest. Mr. Grieve reports, that respecting the surnace No. 3, with the upper gate drawn alone, with a sull head of water, it will give 15 cylinders per minute, but with both gates drawn, in which case the expenditure of water will be doubled, the number of cylinders are no more than 18; and as it otherwise appears that the quantity of charges relative to each surnace is almost, but not quite, proportionable to the number of cylinders, in the surnace also the disproportion between the water and the charges is as great as in any of the rest, and indeed the proportion, though in somewhat different degrees, appears from the united testimony of the machines of every construction.

Observing this disproportion, and my mind suggesting to me the use that might be made thereof, towards a better allotment of the water, I sound it necessary to know whether the iron produced by the several surnaces at their low rates of working was as good as the iron produced at their higher rates of working; and from the answers I have received from Messes. Benson and Grieve, it appears that the low rates of working produces quite as good iron as the higher, and in cases of impure mine considerably better; however, it seems there are rates of working so slow, that the iron would not be put in a sufficient susion, would happen if No. 2 was reduced from 18 to 10 or 12 charges per day.

From a diligent comparison of the above particulars with each other, and also with the theory which they ought to conform to, if the experiments could have been made with accuracy, I have endeavoured to settle the proportions in which each surnace would work with an equal distribution of water, according to the quantity in which it was used during my observations on the day of trial, which, according to table 1, was at the rate of 1602 cube seet per minute, say 1600; by this means we shall be enabled in some measure to enter into the merits of each, as well as to elucidate some other points. Supposing then the 1600 seet equally divided amongst the whole sour, each will work with 400 cube seet per minute. Ind their several performances may be expected as follows.

s follows.		Strakes.	Charges.	Cube feet of air per minute.	
Table 3.	No 1.	23 b 25 12	27 16 18 24	1459	
	Total N	to, of charges or table 1.	8 <sub>5</sub>		
	Differen	nce		rous of disposition table 3.	1

If we suppose 1600 feet of water divided equally amongst the three surnaces of table 1, they will each have 533 cube feet per minute; they may then be expected to move as follows:

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N. B. This last disposition, though it advances the number of charges by two, yet as it throws more work upon No. 1 and 2 collectively, and less upon No. 4, which works fingle, I suppose the convenience upon the whole may be less.

The following equal disposition of the water amongst three surnaces may perhaps answer better, as it not only makes a better produce, but divides the work of the two houses more equally.

From the above disposition, I deduce the following probable inferences.

1st. That the number of charges does not depend wholly upon the quantity of air produced by the machines, but in a great degree upon the regularity of the blaft.

2d. That the number of charges does not depend upon the velocity wherewith the air is thrown into the furnace, but rather upon the quantity of air that is made to pass regularly through the materials contained in the furnace in a given time.

3d. That this quantity so made to pass may have its limits, for too much may spoil the metal by over-heating it, and too little will not produce heat enough to give it, and keep it in the necessary state of fusion, and which limits can only be ascertained by experience.

4th. That the worst machine is capable of working a given number of charges with less expence of water than will be required to be added to the best, to advance its produce by an equal number.

6th. That the most advantageous way, when water is short, is to keep down No. 2 and 3 to as few charges as can be admitted to do their business well, in point of quality, and to divide the water, after these are served, equally betwixt No. 1 and 4; but when No. 1, so served, runs above 28 charges, or No. 4 above 30, then such overplus to be equally drawn upon 2 and 3, and so on, upon the waters mending, till they are all advanced to their highest pitch, and the contrary method upon its decline. We

We will now examine the real supplies at the times of shortest water, and endeavour to ascertain the best means of using it.

From the gage of the river's water taken at the long arch it appears, that at that time it amounted to 990 cube feet per minute; but as the water was faid to come down more in the day than the night, on account of stoppage of mills above, and also that sometimes by continuance of drought runs still shorter than at present, it was thought it was in the greatest scarcity on an average not more than ; of what we then measured.

The fire-engine at that time went from 6 to 8 strokes per minute of 5 1/2 feet each; but as the was frequently obliged to stop to gather steam, this with other stoppages in the 24 hours, together with the lofs by shutting of valves, makes me reduce her average rate to five strokes per minute at 5 feet each.

> The fire-engine will therefore raise per minute 440 And the river Carron at lowest Total 1100

I understand from Mr. GRIEVE that No. 3 makes good iron at 15 charges per day, and from Mr. Benson that No. 2 will not answer at 10 or 12; but I will suppose that No. 2 will work as well at 15 charges as No. 3 does, and as they are allowed to work well at that rate, they may be supposed to do so at a somewhat a smaller rate; dividing, therefore, the 1100 feet equally amongst the four furnaces (which reduces No. 2 and 3 nearly to the rates abovementioned) we shall have as follows:

*	Strokes.	* Charges.
Table 6. { No. 1. 2. 3. 4.	21 22 10 3 11 5	23.8 14.1 27.5 cubic feet per minute. 21.2
	Total charges  Ditto per table til  Difference	4 in savour of disposition No. 6.
		· · · · · · · · · · · · · · · · · · ·

Hence it appears that in the lowest state of the river Carren, by disposition table 6th, there will be 4 charges per day worked by 1100 feet of water per minute more than is done by disposition table 1st by 1600.

To compleat this view, I will suppose all the surnaces equally perfect as No. 1, and that they are confined to the supply of the river Carron alone in its lowest state, that is, 660 cube feet per minute; there will be therefore a supply of 165 feet for each machine. These 4 machines with that supply will go  $17\frac{1}{2}$  cylinders each, and work  $19\frac{1}{2}$  charges, in the whole 78 charges per day, that is, 7 charges more without the fire-engine than they do with it at the time that the river Carron supplies 990 feet of water per minute.

In these computations I reject the circumstance that No. 1 and 3 carry about To more weight of one to the furnaces at a charge than No. 2 and 4, which is much in favour of the two former; but as there appears to be several other differences of circumstances as well as those, I rather chose to take the whole in the gross from the number of charges, without dwelling on minute circumstances.

#### Concerning the Nofe-pipes.

It is suggested in the 2d deduction, that the effect of the surnace does not depend upon the velocity wherewith the air is thrown in, but rather upon the quantity of air that is made to pass regularly through the materials contained in the surnace in a given time.

My reasons for this inference are the following: that in all cases the number of charges worked by each furnace are, when proper deductions are made for the friction of the machine, very nearly proportionable to the quantity of air thrown in by the same machine, and though it will hold equally true, that when different quantities of air pass through the same nose-pipe, the velocity will be proportionable to the quantity, and, therefore, in like manner proportionable to the number of charges; yet, as a double quantity of air applied to a double or two furnaces with an equal velocity, produces a double effect, it is most probable that a double quantity of air producing a double effect in the same surnace, is also owing simply to the double quantity of air thrown in, the double velocity being only a concomitant circumstance attending the throwing a double quantity through the same orifice; and this appears still the more probable, as within certain limits a less velocity of air as effectually converts a proportionable quantity of mine into metal as a greater. Now suppose any surnace, for instance No. 1,° will do her work well at 14 cylinders per minute, in which case she is said to dispatch 18 charges with a nose-pipe of 3 inches, if the machine is made to go 28 cylinders, and drive her air through a nose-pipe of double area, viz. 41, she would then blow a double quantity of air, and would only require a double quantity of water; but if fle

is made to blow 28 cylinders through the same nose-pipe of 3 inches, it will require eight times the quantity of water, and yet the number of charges scarcely doubled, and the metal itself, at the best, no better, and in some cases not so good. Hence appears not only the great advantage in point of water, of working a greater number of furnaces at low charges, rather than I smaller number at higher, but also the advantage of applying as wide a nose-pipe acan be admitted, so that the air may really enter the surnace, and not be repelled back again; and in this respect an equal blast will have very greatly the advantage over an unequal one; but I apprehend that it may be practicably known when any part of the air is repelled, because when there is no sensible reverberation on the hand or face, it is evident it must enter the furnace. If, therefore, it should be found, that when No. 1 goes 25 cylinders, all the air will enter the furnace from a nose-pipe of 41 inches, or, for the sake of an addition of velocity to make it enter, suppose of 33, it will then work with 247 cube feet of air per minute, instead of 481, which, per Table 2, is requisite for the same number of cylinders through a 3 inch nose-pipe; and, consequently, if all the furnaces were equally perfect with No. 1, they would be capable, in the very lowest state of the river Carron, (with the present help of the fire-engine) of doing more work than they now do with a full supply of water, and without the fire-engine would do re work than they now do with it.

After all, I do not pretend to determine that things will fucceed exactly in this manner. The physical nature of bodies is not to be circumferibed by geometrical reasonings, which have only quantity for their object; all I mean really to investigate is, that if the nature and conveniencies will, upon trial, admit of their being worked in the manner suggested, then such advantages in point of power will follow; yet I do not mean to say that the advantages will follow precisely in the quantities I have set down; this is not to be expected, unless the data on which I have been obliged to proceed could have been more accurately had: however, notwithstanding a degree of inaccuracy in the data, I presume it cannot be so great but that the reasonings thereon sounded will at least data, I presume it cannot be so great but that the reasonings thereon sounded will at least shew which way the advantage lies, and thereby furnish matter for experiments, which, shew which way the advantage lies, and thereby furnish matter for experiments, which, so they could easily be tried, and if attended with success will be of great consequence in the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage, I cannot but earnestly rein the application of the present powers to the best advantage.

#### [ 375 ]

Concerning the Improvement of the Blast Machines.

No. 1 is now supposed compleat, and a standard for the rest.

No. 2 appears at present to be the most faulty, but when rebuilt according to the plan given in with this report, I suppose will perform at least equal with No. 1 in making iron, and go with ‡ or ½ less water.

No. 3 appears to take confiderably more water than any of the cylinder machines relative to the number of charges; what preference it has in reducing those charges into metal I can be no judge of. I apprehend, however, it would be confiderably improved in its present form if the two blow-pipes were connected by an air-chest furnished with valves, and from thence to blow from one nose-pipe. As this alteration may be easily made it seems worth the trial; but I apprehend it will never perform quite well till it is put into the form of either No. 1 or 2.

No. 4 will, I apprehend, perform nearly with No. 1, when furnished with a fourth cylinder. This I suppose, because when their effects are compared when working with the same quantity of water as per table 3, the difference is not much greater than what should arise from the wrong proportion of the parts of No. 4, which will be in a great measure corrected by the addition of a fourth cylinder.

It would be a faving of water in the whole if the pond of Carron was never suffered to go lower than from 6 inches to a foot below a full head, and rather than suffer that, to draw the necessary water from the reservoir at Larbet, or to reduce a number of cylinders blown at each machine, according to the proportions suggested in tables 3d and 6th.

#### Concerning the Boring Machines.

		Cube lette
The over-fliot wheel in boring a gun of 6 tinches, used per minute		341
The cutting machine		163
	Together	509
But 25 one cutting-mill supplies two boring, subtract half the cutting-mill's water		84
Neat quantity expended to keep a cutting and boring machine at work continually	,	425

In regard to the small boring and turning mill at the side above, I find it takes 495 cube feet per minute; but as I understand it only goes when there is a full head and plenty of water, I lay it out of the consideration.

It appears then, that to keep one boring machine, with the necessary cutting, going continually, they take near \(\frac{1}{2}\) of the whole produce of the river Carron in short water times, that is, almost as much as the fire-engine draws; and though these machines be supposed to go only 12 hours in 24, yet they will still consume as much water as will work the surnace machine No. 1 at 22 charges per day; a destruction of power which has been very properly seen by the Company, and therefore proposed it as very desirable that those machines should be intirely silenced in short water times, and a new one erected in lieu thereof upon the tail water proceeding from all the surnaces collectively.

Now if these 2 machines require 569 cube seet per minute to work them when there is a fall of at least 20 seet, a fall of 6 seet, (which is the utmost I think can be well had for the tail-water into the tide's way) will require 1697 seet; whereas the river Carron does not supply half of this water in very dry seasons, and the engine water will not apply itself to this machine; notwithstanding, I can assure the Company that I can undertake to surnish a design, wherein the atter can be applied in so superior a manner, in point of power, to what it is to the present machines, that the river Carron, at 660 cube seet per minute, upon a fall of 6 seet only, shall drive those machines as essentially as they are now driven with 509 seet upon their present head.

Kerfe-House, July 31, 1769.

J. SMEATON.

RESOLUTIONS of the Carron Company.

AT a monthly meeting city partners of Carron company, held at Carron, 10th of A Just, and following Days, 1769.

Present,

Mr. JOHN ADAMS,

Mr. CHA. GASCOYNE,

Mr. THOMAS ROEBUCK,

Mr. WM. CADELL, jun. and

Mr. JOHN CADELL.

Mr.

Mr. Smeaton's report of the 7th of July last, made in consequence of our letter, dated July 1, having been read to the meeting,

Resolved, That the said report be approved of, and that the necessary steps be taken, as soon as convenient, to make such trials and experiments of the use and distribution of the water, according to the tables contained in the said report.

Resolved, That Mr. SMEATON be requested to give the company a scheme and plan of the boring-mill mentioned in his report, as soon as it suits his conveniency.

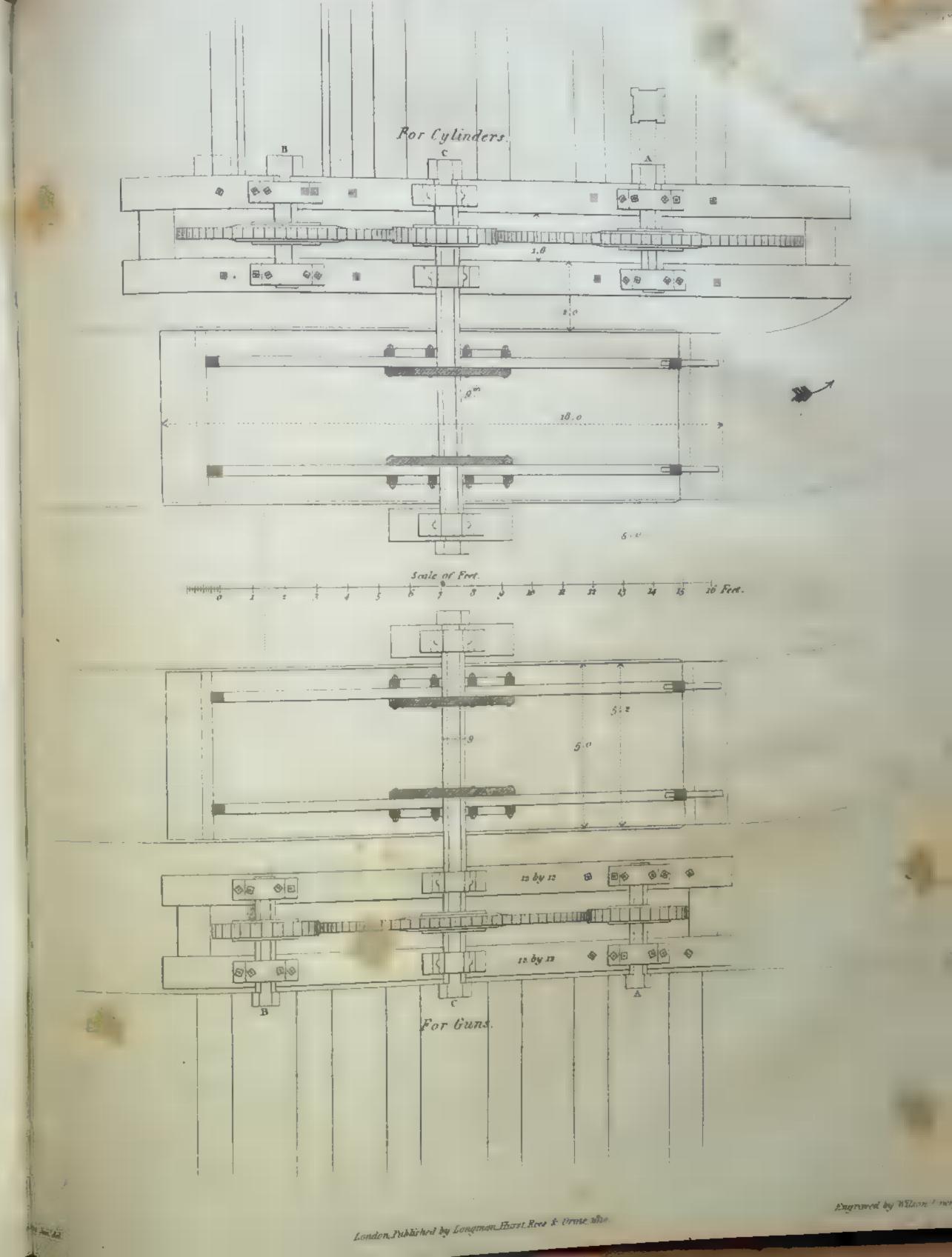
Resolved, That the thanks of the meeting be transmitted to Mr. Smeaton, as a mark of the sense they entertain of the attention he is pleased to pay to their works.

CHA. GASCOYNE, P.

-Some Remarks concerning the design for a double boring mill for cylinders and guns, to be erected upon the tail-water of the Carron works.

I propose the machine to be erected upon the opposite side of the tail water-course to that on which the blast surnaces stand, and in any part of the yard that upon the whole shall be thought most convenient, which depending upon a great number of circumstances that I cannont be acquainted with, must be judged of by the Company; nor is it all material to the action of the machines whether they stand as close to this water-course as they can well be disposed of, or be carried surther into the yard. According to the general design No. 1, it is proposed to turn the tail water course of these mills a quarter round, so as to proceed nearly in a parallel direction to that of the present course to Stenbouse mills, and to fall into the tail water-course at Stenbouse mills, at such point as shall be thought most convenient on account of digging, separation of lands, &c. but in case the tail water-course is made to fall into that of Stenbouse, above the lowest point, to which Mr. Laurie levelled, it will be necessary to clear up so much of the old water course as shall prevent any material loss of fall between that lowest point and the falling in of the new water-course.

Mr. Laurie makes a fall of 8 feet 5 inches from the bottom of the furnace tail lead, at the lower side of the bridge next below the boring-house, to the lowest point to which





he levelled, but as the furnace tail lead will be charged with some depth of water above its bottom, before the tails of any of the farnace wheels will be affected thereby, we may account the whole fall, from furface to furface, to be somewhat more than he has stated. In the present design I have supposed a neat descent at the mill of 7 feet only, for this principal reason, that I observe the ordinary spring tides slow within about 3 feet of the top of Stenhouse mill-dam, and as the neap tides flow within 4 fect at the height of the spring tides, I have therefore laid the wheels so that they may not be interrupted daily by the tides. I propose, therefore, that an over-fall of 50 feet length in the crown be erected at or near the place where the present one now is, at Stenbouse mills, to be laid 3 inches lower than the height of the water in the tail water-course at the works, when the wheels there are just free of tail-water, by which means the whole water will be vented over the over-fall, without affecting the furnace wheels, when the tail-mills are all shut; the height, therefore, of the water marked in the design for the waterwheel to be of 1 foot 3 inches above the crown of the fall, will be 1 foot 3 inches below the top of the over-fall; and allowing 2 inches for the run of the water from the works to the over-fall, this crown will be I foot 8 inches below the highest state of the water in the tail water-course, " will not affect the furnace wheels; but in case all the water from the furnace ca har over Stenhouse dam without putting them in tail water, then this over-fall will be unnecessary. The rest of the fall to Mr. LAURIE's lowest point of level will be I foot, or something better, for declivity between the boring-mills and the said lowest point; but if it shall appear upon further examination that the wheels can be laid lower than I have supposed, without being affected by the ordinary neap tides, then I would add so much to the fall of the mills marked in the said water-wheel design 5 feet 9 inches, keeping the crown of the fall at the same height respecting the surnace-wheels, or not exceeding 1 inch or 2 lower; and for which, if necessary, I will send a new curve for the fall, every thing else remaining the same. It is therefore the height of the neap tides at high water that determines me as to the fall to be taken at the boring-mills; and as this height will not be diminished by any cut that may be made on the loops of the river below, that circumstance may fairly be laid out of the question, there being at present more descent to Reay's Ford than can be taken in for the reasons abovementioned.

The power required for boring depends so much upon the circumstances of the thing to be bored, that it is a matter that cannot be reduced to any exact calculation; but this I am not in the least doubtful of, that in the very lowest state of the Carron water it will carry the gun-mill with two guns boring and one cutting off, which is, I apprehend, more than the three machines at present do, and that in all ordinary times the cylinder-more than the three machines at present do, and that in all ordinary times the cylinder-mill requiring less power, may be worked at the same time. It will, however, be nemill requiring less power, may be worked at the same time.

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cessary that the mill-gates, &c. at the Stenhouse mills be kept in good repair, otherwise a quantity of water will be expended there in leakage.

The rings of the two water-wheels I have designed to be of cast iron, in order that they may act as loaded slies, and thereby preserve the motion more steady.

I have supposed all the axes to be of cast iron, with fluted heads instead of squares, to keep them from wearing off the corners, and are what I would recommend; but forged iron spindles with square ends may be made use of instead thereof, if better approved of, for reasons I don't see. I have shewn the same stuted heads upon the two ends of the water-wheel axis that are next one another, by means whereof, if an extraordinary occasion should offer, the power of both wheels can be combined so as to act on either side.

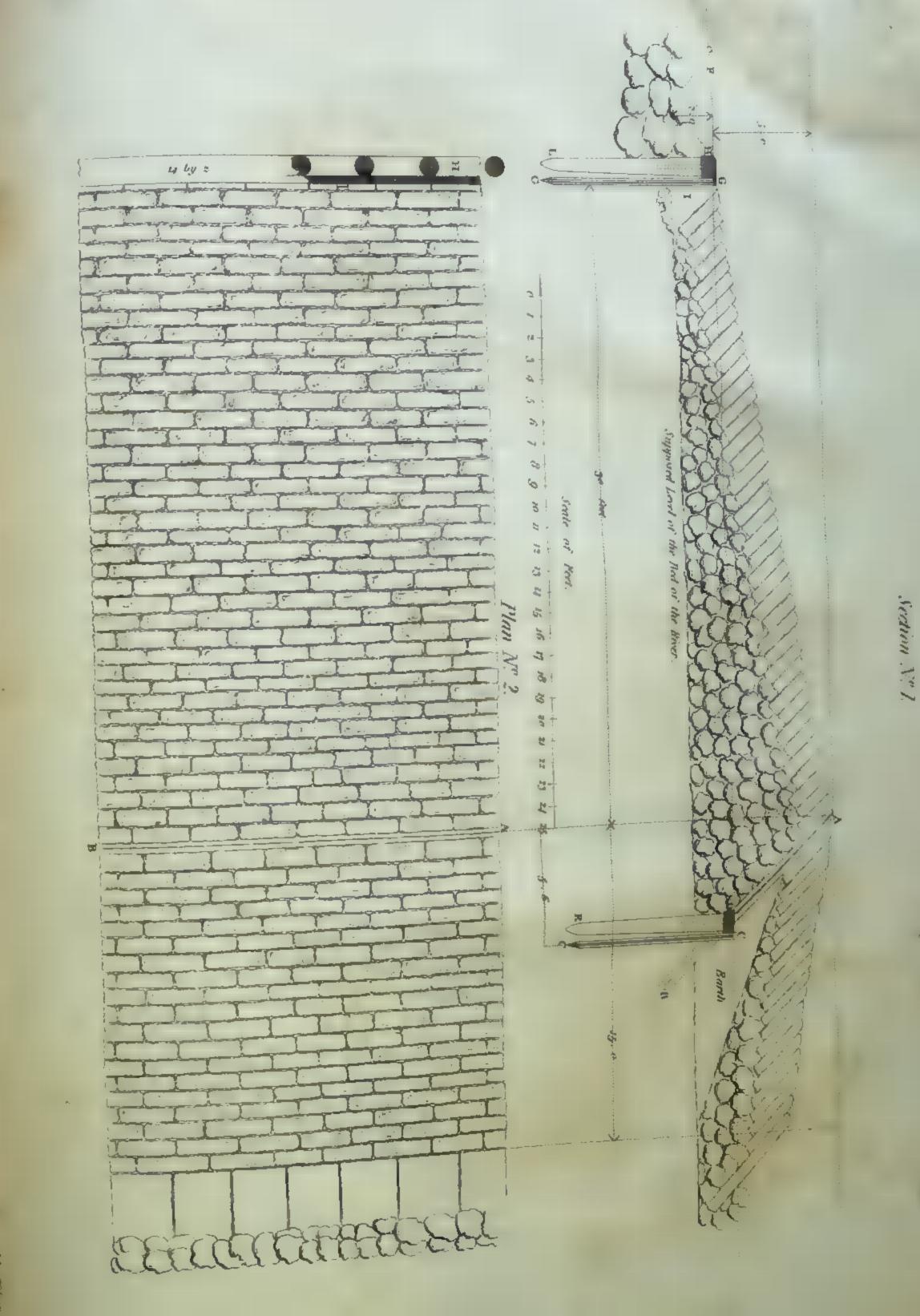
I have been in some doubt whether so large a wheel as is represented for boring the large cylinders could be cast upon that plan; if not, the same fized wheel of 78, as is represented on the main axis for guns, being applied on each side, answers to the mean motion for cylinders; and I apprehend it may be worth while to have two motions, as the wheel will bore two cylinders at once, or a cylinder may be placing on one carriage and got ready while the other is boring: as the motions stand in the plan they answer nearly to 3, 2, and 1.

If it is found convenient to have the boring-mills fo much further from the furnaces that the gangways may come towards the present tail-water course, then the quarter round turn may be made in the new lead to be cut from the same to the new mills, so that the tail-water of the boring-mills will go away directly without any turn. I don't mention this as preserable to the situation in which they are shewn in the plan, but as an hint to shew the different situation in case it should happen to be more suitable to the general convenience.

N. B. A beam being supported alost across the three gangways for the guns, with a tackle hanging from a running roller upon the beam, will take up the gun from the gun-head carriage, and put it upon either of the boring carriages. The same may be done by a crane in the middle.

The width of the new tail-water course should be a 10 seet bottom with proper slopes, but where walled 9 seet will be sufficient.

Concerning



Concerning the alteration of the present mill for cylinders and gun-heads, if the same motions are adapted thereto as are designed for the new mills, they will equally answer. But it would go with still less water if the wheels were made so much lower as to be overshot.

In its present state it would go with far less water, and do its business better, if the motion it now has for gun-heads was adapted for cylinders, and the cylinder motion (that is, of the great axis) was applied to the gun-heads; if made new it would be right to use iron rings for the sake of the weight, whether of its present size or reduced to an overshot.

JOHN SMEATON.

Austhorpe, October 15, 1770.

EXPLANATION of the Delign for building a Dam for the Carron Works at Duni Poce.

THIS design is made upon a supposition that the bed of the river where it is to be built lays about 7 feet below the level of the pen required. Mr. Gascoton's letter of January 16, acquaints that the bed of the river is 4 feet deeper than the top of the fill of the flood gates; supposing therefore the water over that fill at dam's height to be 3 feet, the whole height of the dam's crown above the bed of the river will be 7 feet, as drawn in this design, of which the declivity of the slope surface of the dam is intended to be 5 feet; but it the height of the dam's crown should require to be either higher or lower by 1 foot, it will make no material alteration in the defign; for if it is higher than 7 feet, as it is presumed that this is reckoned from the deepest part of the bed of the river, there is no need to increase the declivity of the slope surface of the dam between the crown and the skirt; but if it is lower than 7 seet, the slope of the dam may be diminished so much as to leave the skirt about 2 feet above the bed of the river.

It is obvious from the defign that the body of the dam is intended to be of quarry rubble; and as the greatest part of what relates to it will be readily comprehended from the design, it will be sufficient to explain those things that are less obvious.

A B, No. 1 and 2, represent two courses of slags or flat stones from 2 feet to 3 feet square, or oblong, as they can be got, and of 4 or 5 inches thickness: those slags are proposed to form the grand stop or pen of the water: if the whole bed of the river at the place where these rows of slags are to be footed can be come at, so as to get them inserted about so foot below the bed of the river, it will be sufficient without any piles for footing the same upon; but if this should prove otherwise, it will be proper to drive a row of grooved sheet piling, as represented at C C, No. 1, supported by a string piece D, and that supported and trenailed down upon the bearing piles D E; this piling to be carried on at least across such deep part where a proper sooting for the slags cannot be come at, and the terminations secured with the projecting part of the slags so as to make nearly a water tight joint: but was it not on account of expence it would be still more eligible if this low of piling was carried quite across, and inserted into the dam's end walls.

At any rate, the first thing to be done, is to lay in so much rubble as will support the sloping flags, and fill up the downstream side of the sheet piling, so as to break the fall of the water over them, at the height of the ground line DF; while this is doing, it will be proper to go on with the sheet of plank piling at the tail of the dam G G, supported in like manner by the string piece H, and that by the bearing piles HL, and the whole is covered by a 2 inch fir plank to preserve the parts above-mentioned from the wear of the water, and which may be renewed when worn out in a course of years, without disturbing any thing upon which the folidity of the structure depends. This sheet of plank piling in all grounds that are not rocks, is indispensible; but as the use of them is not to stop the water, but to keep in the sand and other matter, if the expence of grooving the plank piles is thought material, and the ground is sufficiently uniform to admit their being drove close edge to edge, without grooving, then this part of the business may be dispensed with: by the time the tail sheet piling is compleated, the whole area betwixt C and G should be got filled with rubble, and the row of stones marked I, which are supposed to stand edgeways to the rest, are to be got into their places: in this situation the dam will be entirely fafe from derangements by floods, which will go over the work without hurting it. As the work advances, the flag stones A B are to be got in gradually, pstream setting as shewn in the apron of earth upwards of the flags, and the rubble : the section.

It is to be noted that the two rows of flags are intended to break joint one upon the other, and to be scappelled so as to lay or to pack together tolerably true; the joints all the way up are to be well stuffed with sog or live moss, and to be bedded with the same between the two rows of flags, this will prevent the earth from being forced through the joints

joints by the pressure of the water, and will render the whole perfectly water tight if properly attended to; the earth itself being guarded by the rubble and setting above it.

While the dam is raising, there is no doubt but that the speats going over it will scoop out the ground below the tail sheeting, so as to become 2 or 3 feet deeper than the natural bed of the river; when this happens the whole must be silled up with whin stones, or, what is best, large whin stones split into three or sour pieces by powder, which will enable the angular fragments to stick together better then the whole round stones; and if any derangement happens here by speats, which is the likeliest place to happen, it must be attended to, and supplied till the water makes its exit from the tail sheeting by a regular declining current.

I think it not only unnecessary, but impracticable, to give directions about the building of the dam's end walls, as I cannot determine the situation of the body of the dam respecting the land on each side from any thing that is before me, and the method of returning the ends of the walls into the land, shewn for the dam at Larbet, will be sufficient guidance here; I have only to remark, that it will be proper to make those walls, for some space on each side of the crown of the dam, higher than any flood is known to rise, and that the back of the walls, where the ground is disturbed or new made, must be well covered or even set with quarry rubble, in case the flood water is liable to get behind them from the adjacent haughs; for want of this precaution, I have in more instances than one known the river to make itself a new course round the outward end of the dam.

It will also be proper to make the crown of the dam about 3 inches higher at the ends than the middle, and especially towards that end where the water is disposed to act the strongest, when the crown does not make a line right across the river, which is not always proper.

Table shewing the expenditure of water, &c. in the surnaces at Carron, inclosed in Mr. Smeaton's letter to Carron Company of the 23d of July, 1776, in answer to theirs of the 14th ditto.

Number of the fur- nace.	Day expend-	Cube feet of air protruded per minute.	Velocity of the protruded air in miles per mi- nute.	Proportional ef-	effect produced by	ufed more than
					Tons per day.	Tons per day,
1	11774	1288 7	8.838	100.672	10964	810
2	15760	1673.7	9.298	144.711	15760	
3	17630	1344.2	8.117	88.575	9647	7983
4	24972	1301.5	8.926	89.585	9757	15215
	70136		Fire		46128	2.1008

DIRECTIONS and Observations concerning the clay-mill to be built upon the tailwater at Carron.

THE water-wheel, its conduits, and gate, to be in all respects the same as those of the boring-mill, except that the rings need not be of iron, observing, that in order to preserve the same head of water over the crown of the fall, that the whole be laid a few inches lower, in order to allow for the run of the water from the yard of the works to the place of the clay-mill.

I suppose the rollers themselves to be nearly the same as those now used, and to be cast upon wrought iron spindles or gudgeons: the principal difference here proposed, besides that of a very different proportion between the turns of the water-wheel and the rolls, is the addition of a sly to each roll, a larger to the driving roll, and a less to the roll driven; those are intended to keep the motion more uniform and steady, and so as not to affect the geer that drives them by the little inequalities in the passage of the clay.

These rolls are intended to go about 50 turns per minute, which, as it is considerably quicker than the present, it would greatly tend to make the work go persectly smooth and pleasant, if they were but 18 inches instead of 2 feet length, and yet they by their greater velocity will dispatch more work.

The

The work is so placed that if stampers are desired, they may be applied for beating the clay, so as to prepare it for the rolls; but if the grinding it to a fine tough passe would be of use, for this purpose nothing would equal the runners on the edge, such as are used for oil and gunpowder mills: this would perform the whole operation from first to last, but would not reduce the clay to the consistence that the rolls do, so speedily as the rolls. A work of this kind might afterwards, if sound occasion, be added to the other end of the axis, or in its present form it is capable of having a boring apparatus, or even a forge hammer applied to it if thought proper; for this reason, I would advise to make the building roomy, (of which I suppose the water-wheel to stand crossways in the center) or to leave room on each side for building. I apprehend the wheel will stand best crossways upon the present lead or leet, so that the building will range along-side thereof. In this case, the tail-water must be turned with a quarter round, the more gentle the better, but if need be, may be turned almost in its own breadth.

This water wheel will drive two fets of rollers at once, at each end, or other equivalent works, and for one pair of rolls will go with so little water, that I believe you will scarcely find the corn mill the worse.

I. SMEATON.

Austhorpe, Feb. 21, 1777-

The REPORT of JOHN SMEATON. Engineer, concerning the quantity, regulation, and distribution of the water for working the Blast Machine for the four furnaces at Carron in dry seasons, together with the improvements that may be made therein, so far as regards the power of water to be employed.

Norder to answer the above purposes, I shall not only found myself upon the observations I made myself upon my view thereof in October 1776, but also upon such deductions as may be made from a thorough revisal of all the observations I have formerly made, or that have been communicated to me, of the state of these machines, by the Company at different periods; and the several computations thereon having in general been performed when I was from home, and thereby not having the opportunity of recourse to my former papers, they have been drawn up in different terms, and with different views of the subject; and also observing, in the course of my last view, some particularities which could not be so noticed when the measures were sent me, which would materially affect the calculation of the quantity of water expended, I have in the following table corrected the same, and reduced the whole to the same standard.

Table shewing a comparative view of the several Blast machines as used at Carron, at different periods, from the year 1769 to the year 1776 inclusive.

	No.	Diameter of nofe- pipe.	Number of cy- linders.	Cube feet of air per mi- nute.	Velocity of air per fe- cond.	Tons of water expended per 24 hours.
69, working with short water,	t	3	19	1066	3611	10680
	4	2 5	15.3	1820	803	31200
			Sum	z886	11641	41880
			- Mean	1443	582	
itto, with full blast, -	I	3	25	1403	475 <del>1</del>	19240
	4	2 %	18	2258	945	34080
			Sum	3661	14201	53320
			Mean	1830	710	
773, February, with full blaft,	1	2.	20	1122	547	
	1	2}	18	1255	557	
	3	21	17%	1237	747	
	4	2 (	10	1183	577	
			Sum	4797	2428	
			Mean	1199	607	
276. Inly, with full blatt, -	1	2 <u>1</u>	23	1289	778	15245
1101 ) 1111	1	21/4	24	1674	818	15506
		278	19	1343	691	18210
	3 4	2 t	11	1302	785	25669
			Sum	5608	307 <b>2</b>	74630
			Mean	1402	768	
Ditto, on view in October, wit	h 7	-1	28	1571	947	16502
full blatt,	"}1	21/4		1708	835	16047
	2	21	241	1343	691	15732
	3	278	19 12¦	1459	881	17769
	4	24	Sum	6081	3354	66050
			Mean	1520	838	
			Ddd			Fro

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From the above table it will evidently appear, that the machines, when worked with a full blast, have taken less and less water, ever since the first view in 1769. It also appears, that the quantity and velocity of the air does not observe any regular proportion to the quantity of water expended: but it appears in general that the less quantity of air is discharged from any given machine, and the less its velocity, and the less water in will take to work it; this also is obvious from what occurs every day, that more water produces more blaft in the fame machine, and the contrary,

A state of the works in February, 1773, I received from the Company, with this observation: "From our present experience of the matter, the number of strokes ger " minute, quoted in the annexed table, throws the air into each furnace with a degree of velocity fufficient to keep the hearths open, and to work each machine with due " steadiness and regularity." Now from hence it appears, in particular, (see the precedling table, 1773,) that the quantity of air discharged, as well as the velocity wherewith it was projected, was remarkably near the same in all the four machines, the mean quantity being 1199 cube feet per minute, and the mean velocity 607 feet per second, on supposition (as in all the rest) of its being discharged with an equal velocity; and as, at this season of the year, I can apprehend no scarcity of water, I must suppose the furnace then working with full blast and effect: and, as I am furthermore told, in the Company's letter of the 2d of March, that " for some years past we have fallen into " the method of making the iron at the blast furnaces into pigs proper for remelting " in the reverberatory furnace, for the purpose of working up our gun-heads and run-" ners, which practice requires less velocity of blast than when we cast the guns immediately from the blast furnaces, and also admits of more regularity in the whole pro-" cess; so that perhaps we can now manage with less water than it was thought we could " have done in 1769 or 1773," I say, these things considered, we may ground ourselves here, that if 1200 cube feet of air is thrown into each furnace per minute, and with a velocity of from 5 to 600 feet per second, we shall certainly have sufficient blast to keep all regularly going in times of scarcity of water. I am therein also informed, that many experiments having been made in consequence of my report of 1769, " from " all which we can clearly collect, that a nose-pipe for our purpose should not be less " than 21 inches, nor more than 23 inches." Suppose then that the nose-pipe to be settled at a mean between them; viz. 25, it is not to be doubted but a little less water upon the wheel when the furnace is new, and a little more when it is worn wider, will equally answer the end as a variation of the nose-pipe, as has been remarked by the workmen as necessary: 1200 cube seet of air per-minute driven through this nose-pipe will produce a velocity of 532 feet per second; and that this will be fully sufficient to keep all regularly going, though perhaps not producing the greatest quantity of metal, is evident from the state of the futnace No. 1 in 1769 and 1773. The-nose pipe being now proposed the same in all, viz 25, 1200 cube feet of air will be discharged per minute when the different machines go respectively as follows:

> No. 1, 21 32 cylinders. No. 2, 17 135

No. 3, 16 2

No. 3, 10 14

But as fractions may be inconvenient to the workmen, I will suppose that in short water times the feveral machines are regulated to the number of cylinders, as in the following table; and then the quantity of water that may be expected to be expended, proportionable to what I found in October, 1776, is contained in the four last columns of the following table:

A Table shewing the expence of water according to the regulation proposed for short water seasons, and according to different states of improvement of the machines.

No.	Cylinders per mi- nutc.	Cube flet of air per mi-		Tons of water ex- jended per day, as per Oct. 1770.	Expense of water line; 3 and 4 im-	Expense of water of all improved to a callest falls	Expense of water of all improved to a 24 feet full.
		1774	547	12966	12,60	12312	11800
1	2.2	1234	536	11789	11780	10251	9824
2	18	1255	533	14076	13240	12240	11730
3	17	1202		15852	12312	12312	11803
4	11	1301	5-7				
				54583	49307	47115	45154
	2	1	4	5	b	7	8

By the first table it appears, that the blast machines, as they were working in October, 1776, were confuming at the rate of 66,000 tons per 24 hours; but by the disposition and distribution according to this last table, without any correction or alteration of the machines themselves, that quantity would be reduced to about 54,700 tons; and as it appears that the principal defects of No. 3 and 4 arife from their not taking their water to high upon their respective wheels as No. 1 does, in case these two were altered so as that the top of their upper gates should be 23 feet above the bottom of their respective wheels, then the four furnaces may be expected to work with the quantity exhibited in the 6th column, viz. about 49,300 tons per day.

If all the four furnaces were furnished with upper gates, and No. 2 wheel made larger, for as all to take the water at the same height, viz. 23 feet above their bottoms, then they may be expected to work according to column 7, that is, 47,100 tons per day; and if they were all made to take the water 24 feet above their bottoms, then they would work as per column 8, that is, with 45,200 tons per day.

As No. 3 is proposed to have an high gate, and the wheel of No. 4 to be rebuilt, and as I suppose both will be done this summer during the season of scarcity, it appears that no other provision will be wanted for the approaching feason than per column 6, that is, 49,300 tons per day, because, if one of the furnaces is laid off in order to be reformed, there will be a full sufficiency of water for the other three; for it is ascertained that the river Carron in its lowest state affords 660 cube feet per minute, amounting to 26,400 tons per day, so that a supply of 22,900 tons per day is the utmost that can be wanted to keep all going; and this quantity can be raised by the fire-engine in its present state at the average rate of 61 strokes per minute, which as she may very well perform, it seems adviseable not to embarrass the progress of the other business by rebuilding of the engine this season, but to give her a good overhaul to render her performance secure \*.

It will now be proper to enquire what is to be refered from the home refervoirs, made and making, towards supplying the 22,900 tons per day, above stated as the deficiency of Carron in dry seasons; and I suppose the dam-head of Larbett is to be advanced one foot higher, and all the banks raised in proportion, so as to pen the water in the furnace pool and bog reservoir to 27 seet above the bottom of the furnace-wheels; these reservoirs are stated altogether at 36 Scots acres; and as each Scots acre upon 1 foot in depth contains 1521 tons, the 36 acres will contain 54,756 tons, and upon 3 feet depth (supposing the same surface at a medium) will be contained 164,268 tons, which, divided by 22,900, gives 7 7 to days.

Now when 3 feet is drawn off from 27 feet, there will remain 24 feet, which will reduce the head upon the gates at 23 feet to 1 foot, and as this is as low an head as the water can properly act upon the wheels, it will then be time to seen the lower gates to draw off the remainder. As the water will there act to a confider. ... disadvantage, it will be ineligible to use the engine, but when the surnace-wheels take their water from their upper gates; whatever, therefore, is drawn out of the furnace-pool below the 24 feet, mult replaced again before the engine-water can produce the proper effect upon the wheel

and as this will create a pause or stop of the whole, it will therefore be proper that it be as short as possible; for this reason it would be proper to have a stop-sluice upon the lead in the narrow part east of Mr. Lowe's house, to shut down when the surface is reduced to 24 feet, so that the Carron may constantly pay its tribute by cascading over the faid stop, and then the furnace pool only, properly speaking, with the bog reservoir, will be emptied together below the 24 feet. Now suppose that from hence 2 feet more is drawn, which will nearly empty the bog refervoir, if the wheels take this water at 21 feet above the bottom, then they will expend by these lower gates, to produce the same effect as before, at the rate of 55,200 tons per day, from which deducting 26,400, the supply of Carron, there will want 28,800 from the reservoirs. I must here observe, that the quantity that we can in reality draw off, will be only from the bog refervoir, for what is drawn from the furnace-pool, will be again supplied from some recource above the 24 feet, in order to fill it to the level of 24 feet in common with the lead and Larbett dam, because what is reserved in the dam of Duni Pace, or elsewhere, in order to fill it, might, if not so wanted, have been discharged at the upper gates \*. Two seet then upon 24 acres is 73,000 tons, which divided by 28,800 gives 2 100 days, and this, with 7 100 from the first 3 feet over all, makes in the whole 9 7 days water, a treasury very effential to prevent frequent stoppes and those of thorr duration, but no ways adequate to the purpose of going through a long drought, which generally happens once in a fummer.

We will now see how the account will stand, on supposition that the high gates are all fixed at 24 seet above the bottom of the furnace-wheels, instead of 23 seet before supposed, all the rest remaining as before stated. Now as only 2 feet can be drawn off from the whole 36 acres, they will contain 109,512 tons; and on supposition that the effect is greater from a fall of 24 feet than upon a fall of 23 feet, in the proportion 24 to 23, then the quantity of water before specified to be wanted at the high gates, viz. 49,300 tons, will be less by the part, viz. 47,200, from which taking 26,400, the supply of Carron, there will remain 20,800 to be supplied from the reservoirs; and then 109,512 tons, the content of the uppermost 2 feet, divided by 20,800, gives 5 16 days. Again, we shall now have 24 acres up - 1 feet deep, that is, 109,512 tons in the content, and the lower gates being suppor dat 21 feet as before, we shall have the same divisor, viz. 28,800, which gives us 3 700 days, and which added to the former make 9 700 days; beace it appears, that this latter proportion of 24 feet height of top gates does not make so much of the reservoirs as of the former 23 seet height; but this regards only the

<sup>.</sup> By the way, the greatest desect of the present engine is the not having a sufficiency of steam; and for this reason, the speediest remedy would be to cast and set up a new 10 seet boiler in the manner of those at Cronitade, which may be placed so as to serve the new engine when erected without a removal. and

The communication-stop between the bog reservoir and furnace pool before such filling must that in, so that when the furnace pool is filled, the hog referveir may remain empty. bome

home reservoirs, whereas all water treasured up above the level of these reservoirs will doubtless have an essect in proportion to the fall from the gate.

This enquiry, however, leads us once more to fee how very inefficacious refervoirs are likely to be when applied to a long continued drought; and there is nothing to likely to prove a sheet-anchor as a plain, simple, well-constructed, powerful fire-engine, which when it does nothing will consume nothing, and being plain and strong, will be always in condition to work when needed, and the several parts to be easily inspected, so as to see whether they are or are not in working order.

From the above comparison of fixing the height of the highest gates at 23 or 24 sect, they are so nearly alike that the difference may well give way to convenience; and in this respect, unless that steps have already been taken in the works of Carron to the contrary, it would seem to me that the convenience would be in savour of the 23 seet; for, in the first place, it is indifferent to the engine, because she will draw at 23 seet so much water more than at 24 as the wheels will want to use. 2 dly. Having been informed that the working of the forges is become so material an object, that it will be even worth while to assist them with engine-water, it will sollow that it will be worth while to assist them with what will be equivalent to it.

Now on a former occasion I have laid it down, that a properly constructed engine of a 72 inch cylinder will, at 26 feet high, raise 56,000 tons per day; and supposing all the four furnaces reformed and regulated, so as to use according to column 7 of the last table, viz. 47,100 tons per day, Carron furnishing 26,400, there will be only wanted 20,700 tons of engine-water to them, the remainder 35,300 tons to be thrown into the forgepool: now if the upper gates are fixed at 23 feet, they at once take off as much water from the refervoirs as will keep the furnaces going above feven days, whereas the whole of the remainder will only keep them going about 2 1/2 days more; and if engine-water is to be raised for the forges, why not let off the 2 seet remaining in the bog refervoir into the furnace pools, and begin to work the engine 2 1 days fooner; for this will serve instead of so much engine water to the forges, and then all perplexities will be avoided with respect to the use of different gates, as well as all attentions necessary to keep a quantity of water to refill the furnace-pool up to a level to work the upper gates, and also the necessity of a stop upon the lead avoided, as well as every attention to the vieof it, so that the whole will be reduced to this simple point, that whenever the upper refervoirs are exhausted, and the lower ones reduced to 24 feet above the bottom of the wheels, then the engine begins to work, and continues till the water mends.

One thing however must be very carefully attended to during the working of the engine, and that is, as it only circulates the water, without increasing its real quantity, that care must be taken when the engine is working not to allow the boring-mills more water than is coming down into the furnace pool from Carron; and at the fame time, during the working of the engine, that all the water drawn by the engine, and delivered into the pools, be regularly discharged by the surnace and forge wheels, together with the furply of C. rrou; for if less is let down than the engine draws, it will not only deprive the boring-mills of Carron's supply, (which in those cases is the whole they can be allowed:) but Stenbouse dam being reduced, the engine will want water to draw; again, if more water is let down than is drawn by the engine, and Carron's fupply together, then the surplus quantity, after Stenbouse dam is sull, will either run over the dam, or be spent at the boring-mills; but either way the water will be loft to the furnace-pools, which will thereby he reduced without a possibility of raising there, otherwise then by stopping the boring-mills, and letting down no more water than what the engine will draw, and then the pools will rife by the continual influx of Carron. These matters, so very necessary to be regulated, will, I apprehend, be done by strictly observing the following rules, a proper person being as pointed to see to the observance of them.

When the furnace-pools are reduce to 24 feet, let the boring-mills be stopped, either altogether, or at nights, but so long, and at such intervals, as to suffer no water to go over Stenhouse dam, drawing at the same time as much water at the surnaces and sorges as will supply the engine; by this treatment, the surnace-pools will gradually rise to 25 feet by the continual influx of Carron, which in this case they should not exceed.

When you find it exceeding that height, allow a little more water to the forges, and before it begins to run over Stenhouje dam, let the boring-mills draw so much as to keep it under, but not materially reduce it; by this means the boring-mills can never have more than Carron affords, nor the engine less than its proper quantity, nor yet the forges more than the surplusage \*.

The only prefent diffice! Stenbows dam being leaky, and thereby letting a confiderable part of Carron's supply cicape, that should work the boring mills; but having a detable part of Carron's supply cicape, that should work the boring mills; but having a detable part of Carron's supply cicape, that should work the boring mills; but having a detable part of Carron's supply cicape, that should work the boring mills; but having a lighter or punt upon the dam, if sine earth is scattered over the whole surface of the slope, for 30 or 40 yards above the dam, or so fat up till you come at the natural bot-slope, for 30 or 40 yards above the dam, or so fat up till you come at the natural bot-slope, so is 30 or 40 yards above the dam, or so fat up till you come at the natural bot-slope, so is 30 or 40 yards above the dam, or so fat up till you come at the natural bot-slope, so is 30 or 40 yards above the dam, or so fat up till you come at the natural bot-slope.

Perhaps the best husbandry of all, of the reservoir water, instead of throwing the lowest 2 feet of the bag water immediately into the surnace-pools, will be to let it out gradually there into in such quantity, as being expended at the forges, it will, together with Curren's supply, fully work the boring-mills.

tons,

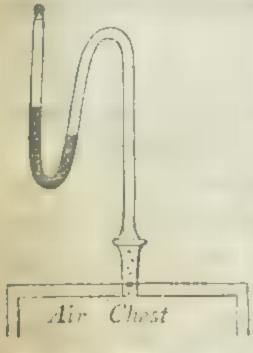
tom, and this being stirred and puddled with cow-rakes, by some pains of this kind of three or sour men for a couple of days, I doubt not but that it may be rendered sufficiently tight for the exigencies of the present year; but if you think not, if you will be preparing a quantity of stone and piling, such as was directed to be used at Dunipace, I will settle the particular plan for it immediately at my return from the Derwentwater spring receipt, which I apprehend will be about the middle of May.

The most pressing thing for this year's service is to make the alterations at No. 3, and new wheel conformable to the above, 23 seet high, for No. 4; but if made 24 seet, as formerly proposed, then all the upper gates must be made conformable, and it will be adviseable to have low gates about 3 seet below the other.

When No. 3 stands still, it will be worth while to get out and rebore the cylinder that is taper, as a confiderable loss of power appears to be there; and when No. 2 is stopped, it will be proper to restore the original conveyance pipes, as not only the straightness of the pipes of 7 inches, since supplied, but the driving the air through a box, when it is unconfined, to a particular direction, is, as I have experienced, a considerable loss of power. The best thing that can be done with No. 2 wheel, will be to clear it of the present buckets and shrouds, to mortice the rings for 16 studs in each, and upon those apply new rings, which, on account of being supported in 16 points instead of 8, need not be above half the scantling of the others; then cloathing these new rings with new shrouds and buckets, it may be made the same size as No. 4, the axis and crank being raised on chocks, and the crank-rods shortened, leaving all the rest, inside the house, standing as at present. The water penstock must also be raised, but if made 24 seet high, should have a lower gate like the rest, and then it must be bucketed the contrary way, and have a penstock of a different kind to throw the water back, in which however near 6 inches of perpendicular will be lost; so that to draw down the pool to 24 feet, leaving 1 foot head upon the penftock, (the over-shot wheels to go the reverse way) cannot be more than 231 feet high.

In regulating the nose-pipes, I would advise their being brought to a clear regular surface inside, to some distance back from their very nose; and if those that are too small are bored to the gage of 2; inches, so as to leave the nose-part a cylinder, I have experienced it in water to throw out a more clean and less scattered column. An attention to this, and also to keep the tuires as narrow as possible, so as just to receive the column and no more, I am convinced of it, will be sound very beneficial in regard to the saving of power, or rather to make the very most of the power stipulated.

The best practical way of keeping the machines to the number of cylinders specified in the latter table, will be to surnish each surnace-keeper with minute glass, such as are used by the shipping for the log; they must, however, be ordered on purpose to be an exact minute, because those made for sea are generally some seconds short, for reasons given by mariners. I have now a couple by me, which I got made in Wapping, for experiments, in better manner than common, instead of sand, being surnished with granulated lead, and are very exact: but after all, unless the leathering of the pistons could always be kept equally tight, an equal number of cylinders will not always give an equal quantity of blast; but if when the leathers are in their best state, the surnaces



were furnished with a gage, consisting of a glass tube, fixed with cement to a bored brass stopple, as per margin, with a little quick-filver, this applied to a hole in any part of the air-chest, or general conveyance pipe, by observing the height that the quick-silver rises in one leg above the other, as much water applied to the wheel as will raise the gage to the difference experienced when all was tight, will not only in all states of the leathers reduce the machine to the same degree of blast, but discover when the leathers are defective, because then it will require more cylinders to keep the same difference of gage. These gages need only to be

applied occasionally, when any deficiency is apprehended, and 1 or 2 may serve the 4 furnaces. If the top of the tube, which is properly to be open, has a bit of porous cane by way of peg, it will not only prevent the quicksilver scattering out, but prevent its vibrating so much by the inequality of the blast.

J. SMEATON.

Austhorpe, April 6, 1777.

Retch for the new furnace No. 5 for my approbation, being upon the construction of No. 2, only the water-wheel placed between the four cylinders, that is, a pair on each side, to which, if you find it more convenient in point of situation, I see no objection, or, if otherwise, no preference. It would be better with respect to the necessary speed of the water-wheel, if the cylinders were not quite so large as No. 2, viz. about 4 feet 3 inches; but as I apprehend you have already a set of models for the bottoms and air-chests ready made, by which No. 2 were cast, it will answer nearly the same end if you somewhat shorten the stroke, that is, not to exceed 4 feet. The wheel should be overshot, and the same height as No. 4 is to be made, and No. 2 to be raised; but by all means let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the separation of the two sets of mameans let the air-chest be continued to join cross the set of the continued to join cross the separation of the two sets of the set of the continued to join cross the set of the continued to join cross

chinery, and the blast-pipe go out from the middle in the most direct manner to the tuite, and to taper from the size originally proposed for No. 2, from the air-chest to the nose-pipe.

In considering further upon the proposition contained in the note annexed to page 8, it appears still more advantageous, if you were to keep part of the water in Dunipace reservoir to apply in the same manner; for by this means the boring-mills need never be short of water, nor yet any reservoir water misapplied on supposition of the forges being supplied with engine-water, or what is equivalent, and by reserving thus a sufficient part of the reservoir water, it will even answer to the leakage of Stenbouse dam, suppose you cannot get it tight in the way I have mentioned.

Keswick, April 10, 1777.

J. SMEATON.

DESCRIPTION of the Apparatus for putting motion, and discharging any of the particular motions for boring the Gasconades at Carron.

Fig. 1. The dotted square a b c d represents the square end of the axis of the water wheel, or any of the side motions driven by toothed wheels therefrom as usual, and whether this is a plain square or citadel head, is here immaterial. To this square end is firmly attached an arm A B, which spreading both ways C D, and applying itself to the angle of the square, this, by means of a similar piece E F G, and a couple of bolts, the arm is brought on perfectly firm and folid, and will therefore continually revolve with the axis. At A is a mortoise through the arm 3 inches broad, and about 14 wide, capable of admitting a piece of iron faced with steel, and hardened, shaped somewhat like a blunt plane iron, but \frac{3}{8} inch thickness, so as to fill up exactly half the mortoise, and consequently its working or steel face will be in the direction of the radius; the sing it: upon this arm may other half of the mortoise is occupied by iron wedges t be supposed to be imbossed, but in reality cast along with it in the same piece a projecting part Befgb before the plane CD, and also before EFG, being attached to the former, but detached from the latter, which projecting piece terminates forward in the ring iklm, which forms a focket H, also cocentrical with the axis, and firmly connected therewith, which being fully understood, the rest will be easily comprehended.

Fig. 2. The square abcd represents the square of a detached axis; the dotted circle e f represents the size of a gudgeon, which is adapted to the socket H in the former significant E square: E D are two projecting arms, that, with the axis and gudgeon, form E at E will be readily understood from sig. 3, which represents a part of the plan of the detached axis, and wherein the same letters refer to the same parts as sig. 2. The center of the cross E D is pierced lengthways, with a smooth hole capable of receiving an inch and  $\frac{1}{2}$  bolt, upon which, as a center is hung in sig. 2, the arm E E G H I K L, which in like manner contains a mortoise at E of equal size and distance from the center, as the former one at E proposed to hold in like manner a steeled iron tooth or kamm, like the former each made to project about an inch from their respective arms, and the steeled saces being contrary ways, they will meet one another with their stat saces; and it being supposed that the gudgeon e f being introduced into the socket E is that when the two kamms are engaged, the detached axis will be made to turn along with the original one whose square is abcd, but not otherwise; this will now be made more plain by

Fig. 4, wherein M is a part of the square of the original axis, N the road, O the square head seen upon the angle, as at a b c d, sig. 1, H the gudgeon of the detached axis, P the bolt hole through the arm sig. 2 and +, Q the main body of the detached axis, R the road (not to confine it while turning the gun, but to support it when the gun is taken away), and S the square socket, that receives the square at the breach of the gun, by which it is turned round; the two arms in this sigure being marked with the respective setters, as the correspondent ones sig. 1 and 2, will receive a sufficient explanation, especially when it is observed further that T is a stud cast upon that arm, which is acted upon by V, a strong spring sufficient to give the arm F F G a constant tendency to go towards the arm A B, and no in dotted lines is a staple to stop the stud and spring from rising too sar, and from carrying the arm beyond its due position.

Now pq represents the kamm of the arm FG, and rs representing the kamm of the arm AB, which overlaying one another, the arm FG will necessarily be compelled to go round with the arm AB so long as they remain in this position; but to disengage it, the outlaying part of the arm EF meeting in a certain part of its revolution with an inclined plane (of wood faced with a plate of iron) that can at pleasure be interposed, this plane or wedge by acting upon the outlayer so as to separate the two arms, the kamms will be released from each other, and the outlayer, resting upon a projecting part of the wedge, will remain at rest, the other arm continuing its revolutions. The gun is then to be removed as at present, and when another is adapted to the square at S, there is nothing to do but to draw away the inclined plane or wedge; the spring throws E e e 2

out the arm F G so as to form a right angle with the axis, and the next time the kamin rs meets the kamin pq it will quietly lay hold of it, and take it along with it, and so continue till discharged as before.

N. B. It is necessary that the edges of the kamms at the leaving each other should be parallel; for this reason they must not be square, but inclined according to the line rt; nor must the edges be quite sharp, but a little rounded; and as the continual chasing of the guns may wear the socket S safter than might be convenient, this socket may be cast with a citadel head large enough to inclose a piece with a common square within it. If the strength of the spring is not sound sufficient to keep the arms together when in sull strain, it is only making the kamms a little proud at the leaving edges, so that being a little matter out of parallel with the axis, they may be made so as to draw themselves together.

EXPLANATION of the Apparatus for holding and pushing forward the boring bars for the carronades without a carriage.

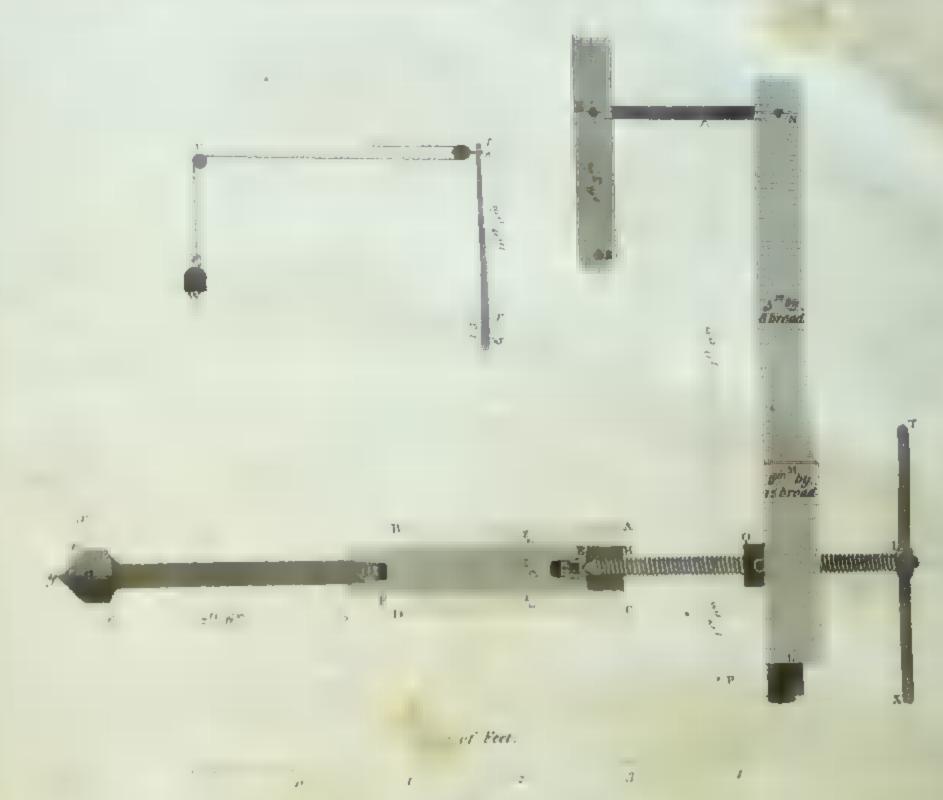
ABCD is the section of a square socket of cast iron, 5 inches square and 2 feet long, which is to be sirmly bolted down upon a proper blocking of wood.

EF is a square of iron of the same size, and 2 seet 2 inches long, which must be sitted to the sormer with some degree of curiosity, so as to slide easily, and with as little shake as may be; this solid piece is to have a tapering square hole at each end, proper to receive as a socket the square of the boring-bar. This would in reality only be needed at one end for fixing the bar GG; but as it may be subject to wear, the lasting will be doubled by having a similar socket at each end.

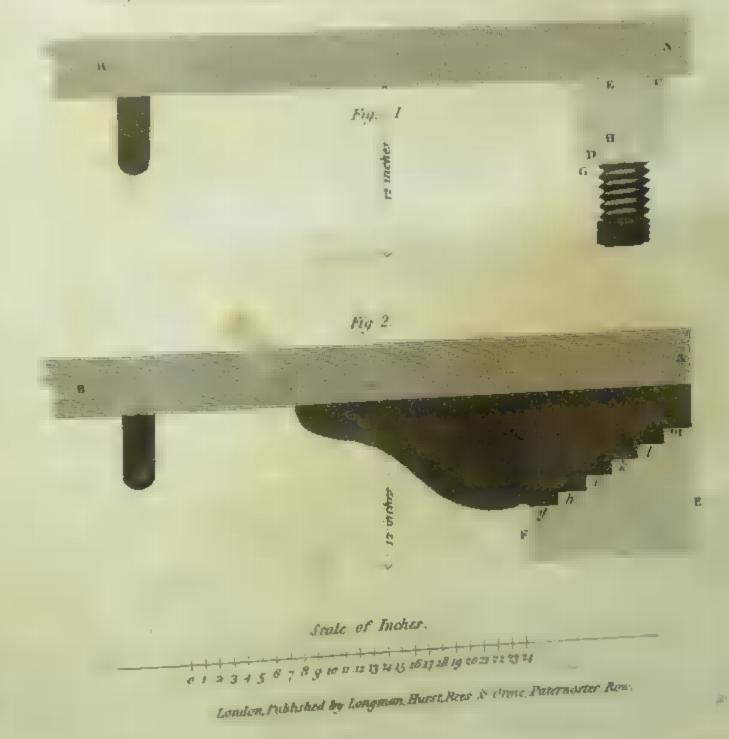
At the opposite end of the solid piece, the piece II is inlaid for receiving the point of the screw I K, by which the solid piece and bar are to be forced forwards. L M N is a lever of wood, sooted at bottom in two strong staples O P, one on each side; the lever L simply bolted and supported by the solid blocking.

Q is a brass or a wrought iron box for the screw, hung upon trunnions as q, so as to give liberty to the threads of the box closely to fit and embrace the screw, notwith-standing the different position of the lever L M N.

N R



Tresign for Two Methods of raising the SLIDE CARRIAGES for the CARRONADES.



Designed by I Smeaten 1779.

Engewed by Wilson.

NR is bar of iron, by which the top of the main lever is connected with a secondary one, whose center of motion is supposed to be at S, and which going upwards beyond the limits of the paper, is represented to a smaller scale srt, where there is attached a single block with an 8 or 9 inch light sheave, and a rope of about 2 inches circumference being reeved, as shewn and passing over the fixed pulley v, the weight W will force the point of the screw against the piece H with any degree of force required; and as don't expect the great lever to work kindly, when more than 1 inch out of perpendicular at the height of the screw, this will give it leave to act by the weight through a space of about 2 inches, when the person attending setting forwards the screw by means of the fixed bar T X, brings up the lever and weight into its original position, and so on, till the bore is carried on to its proper length. The apparatus, in the proportion here designed, will admit of a chase of near 30 inches length, which, I apprehend, will be fully sufficient for your 24 pounders.

N.B. I am told, that a bit, whose cutting edges are brought to proud edge by being filed to an hollow, as is shewn at xy, is marvellously good for boring holes in cast iron; but in this case the two edges cannot be brought into one, but the obtuse angled edge, formed by the thickness of emetal of the bit, joins the two cutting edges crossways, and forces itself forwar y being near the center, but requires a considerable pressure. I am told that 800lb, weight will be required to bore an inch hole; and though these hollow edged bits are not so well adapted to continuance of grinding as plain ones, yet make sull amends by their much less frequently wanting sharpening. How far this kind of bit may be adapted to gun boring, I leave to your trial.

Austborpe, January 9, 1779.

J. SMEATON.

EXPLANATION of the Sketch, shewing the manner of applying the inclined plane for releasing the we the discharging apparatus for the carronades.

Fig. 2 shews the same sace of the work as is shewn in sig. 2 of the design for the lifeharging apparatus sent before, wherein E F G is the discharging arm, and V W is an upright piece of wood capable of sliding up and down, but in no other direction, and the same letters denote the same thing in the side view thereof, sig. 1. to which is attached or made out of the same solid X Y Z, the inclined plane or wedge. In the present

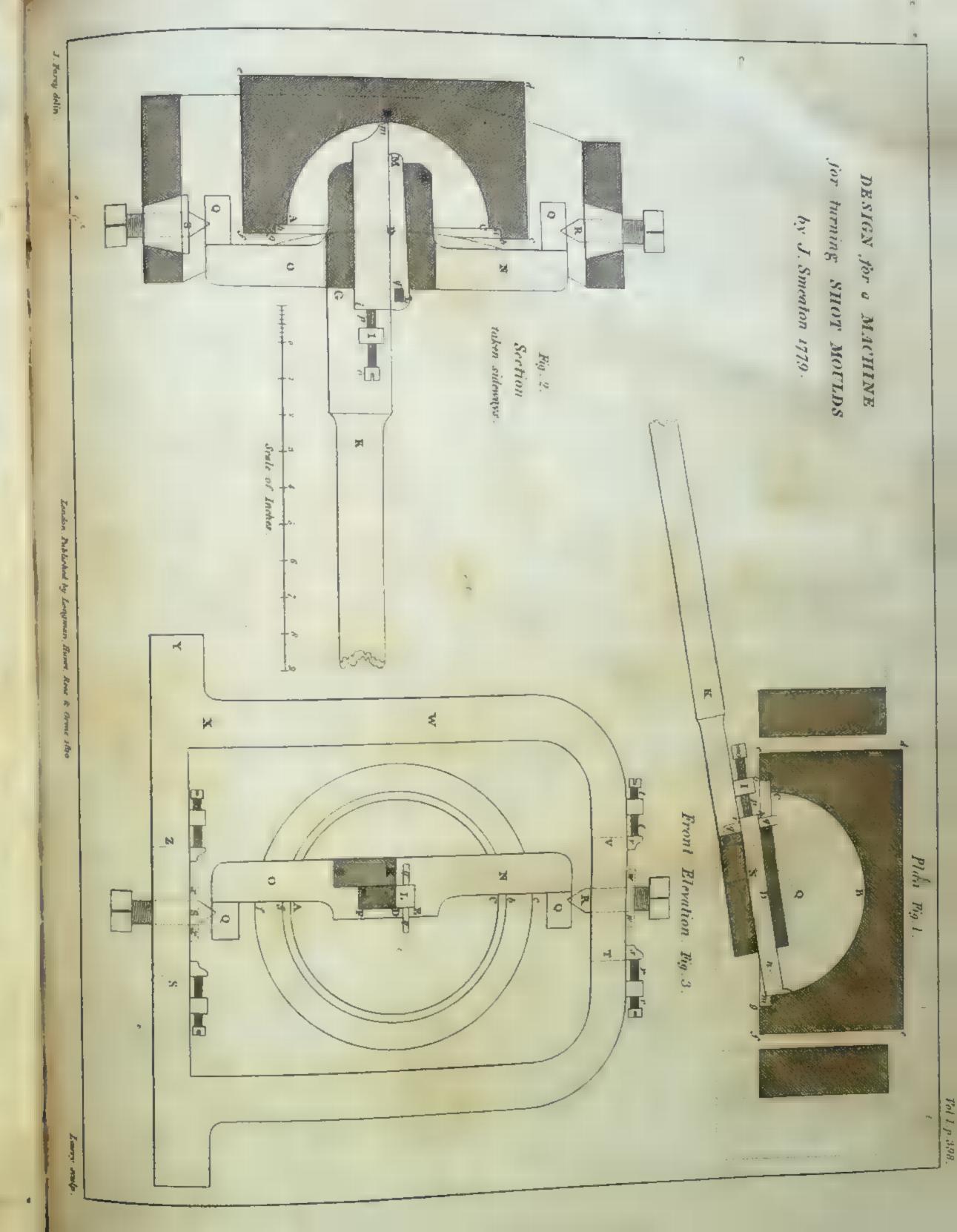
present position of it, it is in a posture for acting upon the discharging arm, and is kept up by means of the catch m n dropping into a notch under the piece of iron at O, when the arm E comes into the position e; it then begins to touch upon the inclined face X Y, and going forwards, by degrees gets discharged before it comes to the position p, which shews it discharged and resting upon the pin q, where it remains till the gun is shifted, and the rotation is wanted to be commenced; then the catch m n is drawn back by a cord, which lets the piece V W drop, till the line X e goes down to the line q r, viz. about  $16\frac{1}{2}$  inches, which entirely clears the discharging arm, and then its own springs it into its working position, where the next time the revolving arm meets it, takes it along with it, and the motion will be continued till the piece V W is drawn up again by a cord, lever, or other equivalent contrivance, till it is supported by the catch m n, when at the first meeting it will be discharged as before.

Austhorpe, January 9, 1779.

#### EXPLANATION of the Design for turning Shot Moulds.

THE semi-circle ABC, sig. 1st, is supposed to be the horizontal section of an half mould, seen from above, which, together with C, a, b, c, d, e, f, g, h, A, is supposed to compleat the whole of the section, and is supposed to be properly fixed upon the arbour or mandrell of a stout chock lathe, capable of turning it with steadiness.

D is the center of the sphere, and, upon an axis passing perpendicularly through this center a frame is supposed to turn, that carries the tool, so as to describe the quadrant AB, and by that means the semicircle ABC, i, k, l, m, is the upper surface of the cutting-tool, l m being the cutting edge. Now if the edge l m be formed into an arch of a circle, whose radius is less than the sphere to be described, and whose center (suppose at n) is capable by the inclination of the frame to be brought into the radius line AD, then it is evident, that if, while the mould fede turns round its axis DB, the tool, by gradual inclination of its frame, passes from A to B, the tool will cut off all superstuous matters that projected beyond its sweep, and also in case the cutting-edge of the tool is regulated to a just height, so as to pass through the center of motion of the mould at B, then it is plain that the hollow figure thus described must be an exact hemisphere.



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Nothing can be more evident and simple than this proposition, the whole difficulty consists in having those exact adjustments that are requisite to perform the necessary conditions, and, at the same time, all the strength and steadiness in the framing that is necessary to work upon and cut clean a mass of cast iron; for this purpose

E F is a section of one cheek, and G H that of the other, of a mortice through the solid metal, for lodging the tool iklm, and the prolongation G K is for the reception of an hollow wooden handle, sufficiently long for turning the frame steadily round upon its axis, while the cutting-edge of the tool is describing the quadrant A E.

Fig. 2 shews an upright section of the mould, wherein the same letters denote the same things as in the former figure, im now shewing the upright of the tool whose cutting-edge is at m, this is pushed towards it works by the screw op, which passes through the stud I, assixed to the projecting part G K, and the tool is tightly held down in its mortice or socket by L M, a wedge, which last is stacked or drawn out by q, a counter wedge. The socket G H, the prolongation or tail G K, are cast in one solid piece with N O, the upright axis, and those with the projecting ears Q Q, which are supported by and turned round upon the points of the screws R S, by which means the frame is made capable of turning round upon the line R C D A S, passing through the center of the hemisphere A B C, at the same time that the frame will clear the face of the mould when in its most inclined position, as is shewn in fig. 1; where observe, that the dotted square G N shews the section of the upright axis above and below the socket, as at N and O, fig. 2, and the dotted space G N Q, fig. 1, shews the figure or plan of the ears at top and bottom, where they engage with the points of the screws R and S.

Fig. 3 shews the fore front of the mould in the lathe, and the same letters will denote the same matters, besides which TVWXYZ, &c. denotes a strong frame that surrounds the whole mould, and supports the screws RS upon which the upright moveable turns upon as a center, as already described, which outward frame is to be simply bolted down upon its stat base upon a stout plank, which plank is to be made to slide with ease and certainty between the cheeks of the lathe, so as to move in a line parallel to the axis of the mandrill, and to fix at any distance required from the end of the mandrill. It is also supposed, that the axis of the mandrill is adjusted as nearly as possible to a parallelism with the cheeks and platform of the lathe.

Now the first necessary condition and adjustment is, that the height of the cuttingedge of the tool shall exactly pass through the center of motion of the mould, which will will best be done by trial, because if it leaves no extuberance in the center, it is plain it has passed through it; if an extuberance is lest, it must be by passing either above or below it, and which of them it is may be seen, and the moving frame set higher or lower, by slacking one and tightening the other of the screws R S, and repeating the trial till the surface is lest without an extuberance in the center.

The second necessary condition and adjustment is, that the line joining the points of the screws RS shall pass through D, the center of the sphere, that is, through the axis of the mandrell produced, which will also be best known by trial; for this purpose, let a gage circle be turned from thin plate brass to the intended diameter of the ball or sphere of the mould; turn out also the central part of the area, leaving it a ring about 3 or 5 of an inch broad, and cut this in two, which will thereby make two gages: thus provided, let a sweep be made for trial, and it will be known by the gages fitting the sweeped surface whether the cutting edge of the tool is at its proper distance from the center, because then the gage will fit the sweeped surface when directed towards the center; if not, let the tool be set forward by the screw p, till they perfectly agree, then running the gage through the center and beyond it, if the gage bites hard upon the further quadrant, then the axis of RS is beyond the axis of the mandrell; but if the matter beyond the center leaves the gage, then it is plain that the axis of RS is on the side of the axis of the mandrell that was the cutting side of the mould, and, accordingly, this is corrected by flacking the screw rr, and tightening the screw tt, or the contrary, till a sweep being taken, the gage every where applies itself to the hollow furface of the mould; and this adjustment being once performed, there is nothing but gradual wear or violence to put it out again, and the gage being applied to every mould, it will always be seen whether any apparent error gradually arises.

The screw r r acts upon the stud S, and the screw tt upon the stud V, both of which are cast upon the same piece of metal with T V, which carries the screw R, and slides slideway in a chamsered groove in the upper bar of the outward frame, as is more particularly seen in sig. 2. I have described the same kind of slide at the bottom Z S, &c. but this is scarcely necessary; for if the whole frame is bolted down upon the sliding plank, so that the line R S may originally be nearly right, when T V is in the middle, the adjustment may be sufficiently performed by sliding the screw R only, for it is no ways requisite that the line R S should be exactly perpendicular; but only that it passes exactly through the axis of the mandrell produced, but it will be necessary that both the screws R and S should have a counter nut, as at the dotted lines www and xx, unless they are made to screw stiffly through their carriage-pieces.

It is to be observed, that, on changing the size of the mould, there ought to be nothing wanting in the way of adjustment, but to set the cutting edge of the tool to its just distance from the center; and as the tool changes in its height by grinding, or a different tool, to see that it passes through the center, that is, supposing the slide of the plank duly performed; and as, upon this slide's being correctly performed, a great deal of the ease and facility of the use of this machine will depend; and as this correctness may feem difficult to arrive at, I will take occasion to make an observation upon lath-making, which may apply itself to several other things in the Carron works. To make the heads, &c. of a lath to slide in a right line between the two parallel cheeks with ease and facility, and without vaccilation or shaking, is in reality no easy matter to perform; but if the near upright face of the further cheek is shot true and straight with a plane, and the upper face or platform of the two cheeks shot straight and flat, that is, out of winding, all which in carpentry is an easy proposition; if then all the matter composing the feat of the heads is cut away or hollowed off, except about the value of 11/2 or 2 inches square, at the four corners, and these prominences brought to a just flat, so as to sit true without shake upon the platform of the lath; if also the far side of the tenant is made to take its bearings at the outfides, fo as to apply itself fairly and steadily to the far cheek of the lath; then, if the heads (or any other sliding piece formed in this way) are pushed home against the far cheek with one hand, at the same time that the wedge or screw is tightened by the other, it is plain that these heads or sliders will obey the same right lines that form the upright sace of the back cheek and platform, and it is then no matter whether the tenant fills the groove or not, but when flacked will be always at perfect liberty. It feems hardly needful to fay, that for correct work the cheeks of a lath should not only be made of dry seasoned wood, but clean and free from cross baits, to prevent their warping after made.

N. B. I am not well acquainted how well the Carron metal works with a file, but, to avoid all intricacy and trouble in forging, I would chuse the work to be cast of gunmetal, or perhaps what may be better, I ounce of tin to 1lb. of copper.

The mould being supposed hollowed to a true sphere, but a little too deep, then there will be nothing to do but to turn down the sace of the rabbat h A C a, till the depth D B is exactly half of the width A C, and then two such will form a sphere.

It is plain from the figure, that to give the tool a proper bearing in its focket, that one upright frame will not do for all fizes; the prefent one is drawn at large to answer any fize, from a 24lb. shot to a 9lb. another one will go from that to a 3lb. under which it will be proper to have one of a proportionable fize; but they will all apply themselves to Vol. I.

the screws RS, and without any other adjustment than that of height. I must, how. ever, observe that the screws R and S must, in proportion to their size, be cut with a fine thread and with sharp stocks, that being first truly turned, they may not cast in stocking, so that when turned round in their sockets, their centers will not sensibly vary. This is a matter requiring attention, but being duly attended to, is not difficult to be practically performed.

J. SMEATON.

Austborpe, 16th January, 1779.

EXPLANATION of two methods of raising the Slide Carriages for the Carronades.

Fig. 1. AB represents the slide carriage plank.

C D. a piece of wood bolted on crossways up. the under side; this transverse piece is pierced towards each end by a female screw capable of receiving a male screw, one of which is denoted by

EF. wood screw 10 inches long in the screwed part, and 2 inches long in the head part F, which is well bound with an iron hoop, and perforated crossways with a couple of holes for small handspikes. The position here shewn of the slide plank is horizontal, or parallel to the deck, which, according to the sketch sent, its under side in that position was 12 inches, and in this position the part of the screw shewn clear, viz. FG, is 4 inches; so that when the head F comes close to the tranverse piece CD, the end A will be lowered 4 inches, and then the top of the screw will just reach to the upper surface of the slide plank, but without reaching through, so that the hole cut through it to clear the screw, may be covered with a thin plate if thought necessary; but if the screw is unscrewed 4 inches more than is shewn in this position of the figure, so that the top of the screw E will come down to H, then the end A will be raised 4 inches higher, and yet the screw will have 2 inches hold of the box, which, containing three threads, will be sufficient to keep it steady.

Fig. 2. A B represents the slide carriage plank as before; CD shews one of two planks, bolted edgeways under the carriage plank, cut into 6 steps a b c d e f, each 1 inch in height, and 2 inches in breadth. EF

E F shews a piece of wood seen endways, long enough to take both the stepped planks, and stepped also into 6 steps, g b i k l m. Now if the height of the lowest step g is 4 inches, and increase by 1 inch, then it is evident, if this stepped wood is drawn gradually back, the plank A will descend 1 inch at a time, till the step g comes under the step e, and the step b under the step f; then will the end A have descended 4 inches; but if from the present position the stepped wood is pushed in one step at a time, then the end A will rise accordingly, till the step m being under the step b, and the step 1 under the step a, so that the plank A, or rather the point a, will be raised 4 inches; and if it is thought expedient to keep them from jumping out of their places, the small staples no being struck in at each end, and the parts lashed together with a marline, this will be sufficient to keep them from shifting the steps upon a discharge, as I apprehend. J. SMEATON.

Austborpe, Jan. 20, 1779.

EXPLANATION of the Design for a new Nose-Pipe for Carron.

Fig. 1. A B is supposed to represent the fire stone that now makes the tuire of the furnace, which is supposed to be of the accustomed thickness, but perforated with a round hole of 7 inches diameter, or of such other width as it may be thought proper first. to try.

CDEF shews the horizontal section of an iron tube serving for the nose-pipe, also of 7 inches diameter, and checked into the stone, and the joint made good with fire clay, which round tube branches out sideways into

CGH and DIK, which are the sections of two oval tubes, whose axis ML and N L meet the axis of the main tube at L.

OPQR represent two dove-tailed sliders, that shut up the orifices of the oval side tubes, so as to be air tight; those oval openings are proposed to be 4 inches wide by 6 inches high, so that on removal of the sliders every part of the opening of the tuire into the furnace may be seen, and the arm and instruments introduced by which it may occasionally be luted, and when thut the wind will take its course from the part of. the tube EF towards CD, in a parallel direction. N. B.

Eff2

N. B. About 8 or to inches of the external part EF is proposed to be kept of width, but from thence to increase gradually tapering to the size of the main conveyance pipe.

Fig. 2 represents an upright section of the main tube at the line S T upon fig. 1.

EF is the main tube.

OP shews the oval hole with the slider drawn out.

QR represents the slider in its place, wherein, if thought convenient, vw in both figures represents an hole, whereto a piece of plate glass being adapted, and fixed in each slider, the condition of the tuire may, at all times, be inspected, without drawing the sliders, or disturbing the blast.

J. SMEATON.

Austherpe, May 2, 1779.

A Comparative View of the State of the Carro: I rnaces in October, 1776, and in September, 1778.

	No.	Gate drawn.	Head of Water,	Dlameter of note- pipes	Number of Cylinders.	Cube feet of air per minute.	Velocity per fe- cand.	Tons of water ex- pended per 24 hours.
State of Furnaces, October,	ı			21	23	1571	947	16,502
1776.	2			2 1	241	1708	835	16,047
	3			2 7 2	19	1343	691	15,732
	4			2 ‡	127	1459	881	17,769
					Sums	6081	3354	66,050
					Means	1520	838	
			řt. în.					
State of Furnaces, Septem-	1	12	3 7	2,1	2	1402	846	16,322
ber, 1778.	Z	07	4 84	21	16	1116	546	11,724
	3	1 %	3 10 2	2 7	172	1237	562	15,285
	4	04	3 01	24	201	1309	529	7,396
	b	Oğ	3 14	2 1	21	1341	542	6,630
					Surns	6405	3025	57.358
					Means	1231	603	From

From the preceding table there appears a great improvement in the dispensing of the water, for in the year 1776 four furnaces expended 66,000 tons per 24 hours, and in the year 1778 five surnaces expended but 57,300.

It is, however, remarkable, that of the last-mentioned quantity, numbers 1 and 3 expended 31,608 tons per 24 hours, while the other three furnaces expended but 25,750, the cause of which disparity it may be proper to enquire; for though every degree of accuracy, I doubt not, has been exerted in the new building of No. 6, and the rebuilding of No. 4, yet there is not that difference in the principle of action that can make these two machines so very much exceed those of No. 1 and 3; for in point of construction I should not expect them to fall short of the performance of No. 4 and 6 more than 20 per cent. This difference I must therefore attribute in a great measure to the different widths of the nose-pipes, which, as I have never heard of their being varied, I take for granted they continue the same they were in the year 1776, that is, as I have put them down. And I have no doubt but that if they, as well as No. 2, were furnished with the same kind of nose-pipes that No. 4 and 6 blow with, that they would then reform within a reasonable disserence of those last furnaces; if not, the rest of the donce must be sought for elsewhere, that is, either in the untruth of the cylinders, too great friction of the leathers, a straightening of the wind passages, or a general disrepair of the machines; all which are matters well worth looking into; for if two furnaces can be worked with 14,026 tons per day, this is lel's than the average quantity for each of the other three, which is 14,444.

Again, although it appears that the expenditure of No. 2 is greatly reduced, owing in part to the removal of Mr. Downtng's incumbrances, and in part to the reduction of the number of cylinders per minute, (which I suppose was also a consequence of the restitution,) yet if the expenditure of No. 2, viz. 11,724 tons per day, be reduced in proportion of 23 to 20 (which would certainly be the case if that wheel was raised to 23 feet high, like Nos. 4 and 6,) it would still expend 10,195 tons, which is 2799 tons per day more than that of No. 4; and as there does not appear to me any other thing in the construction of the machine No. 2, that should make it fall short of No. 4, this extra expenditure by No. 2 rem. To be accounted for, and which in part I doubt not is owing to the difference in its nose-pipe.

That the difference of the friction of the leathers is capable of confiderably varying the expenditure of the water, I think appears pretty plain from Nos. 4 and 6, the former confuming more water by 11½ per cent, upon the leffer quantity, than the latter does; and therefore, as they are both as nearly alike as possible, the No. 4 being the last built

built furnace, it seems most probable that the fides of its cylinders were not at that time got to so great a smoothness as those of No. 6, or that casually No. 4 was at that time harder in its leathers.

Now, if we suppose Nos. t and 3 to be reformed so as to perform within 20 per cent. of No. 4, and No. 2 reformed so as to perform as well as No. 4, then the expenditures will stand as follows, viz.

From this statement it appears probable, that the consumption of all the five surnaces, may be reduced to 39,172 tons per 24 hours; and as Carron surnishes in dry seasons 26,400 tons (see report of 6th April, 1777,) there will then only remain 12,772 tons per 24 hours to be provided for out of the reservoirs; and as it is stated in the same report that the home reservoirs alone contain, upon three feet depth to be drawn off, a treasury of 164,268 tons, this would supply five surnaces at the rate above stated for near upon 13 days; whereas the same quantity, according to the view of the subject at that time, was not likely to serve four surnaces much above seven days. But surther, in case No. 1 or No. 3 were laid off in times of scarcity, or that they both together were allowed but 8875 tons per day to keep them alive, then there would be only 3397 tons per day to be provided for out of the reservoirs, which would last the surnaces at this allowance full six weeks, which, together with the other command of water the company already have, seems to render the building a fire-engine of any construction totally unnecessary, especially if the old engine is kept in working order to serve an emergence.

For some time No. 1 led the van of all the works, now it is got into the rear of all; but if you had an opportunity of applying the nose-pipe I transmitted in my letter of the 13th ult. I have reasonable expectation that this furnace would once more lead the van.

J. SMEATON.

Austborpe, June 11, 1779.

The REPORT of John Smeaton, Engineer, concerning the expediency of opening the temporary Cut and Lock near Dalderse, from the canal of Forth and Clyde to the river Carron.

THE utility of this cut, from Carron shore and parts adjacent, appears from its first construction, which was to bring the stones got from the quarries at and near Kinnaird, and brought down by the coal waggons to Carron shore, there put on board small lighters, was brought through the temporary cut, and brought to build the first land lock, and other works in that quarter; also the lime, pozzelana, and timber were brought for some time that way; and it being a work ordered by the Committee, principally by the advice of Mr. MACKELL, he urged in favour of its expediency, that it would be the properest accommodation to the Carron works, and that (in his way of expressing himself) that Company should never get any other. From this it will appear (which I perfectly remember) what were Mr. MACKELL's sentiments concerning it at that time. On examining it, which, at the request of the Carron Company, I did the 6th of November last, I found both the cu and lock to all appearance in much better condition than I expected; the principal ang wanted to restore it, will be a little more room, to get earth to strengthen and heighten the banks, equivalent to those of the main canal; and respecting the lock, for any thing that appears, it seems to be likely to want little for some time to come, more than new gates; and the lock is of so small a size, that the head of the lock may be shut by a single gate, in such a way as to occasion much less leakage than the larger pointed gates, and in a mode that I first put in practice upon the river Calder, in or about the year 1761, and which the last December I had the pleasure to see in persect good order, without having had any derangement or repair.

The constant leakage being in this manner secured to all small vessels, having a right to pass the canal proceeding singly upwards, as much water will be saved to the last, or search, as is equal to the difference of area between the temporary lock and the canal locks, which is much more than double, and will be more than equivalent to the consumpt of such vessels as may happen to have occasion to go downwards, from the temporary cut; besides, as this reach is of a considerable length, and pretty capacious, and naturally receives the regulating water, and all the leakages from above, there is the least fear of wanting water in this than any other of the reaches.

I remember myself that this accommodation was frequently mentioned as proper for the Carron Company, but which at that time they did not think sufficiently commodious, and near their works.

As therefore it appears likely, that by opening this temporary cut and lock, there will be a considerable increase of freight and tolls, without any loss, that it will, for the advantage of the whole, be a proper measure to be carried into execution.

Austhorpe, 7th February, 1782.

J. SMEATON.

N. B. I apprehend that small vessels will generally pass single, for it is to avoid waiting for freight that larger vessels are not used.

### To the CARRON COMPANY.

· GENTLEMEN,

TT is from what has occurred to me in the experience of 30 years in the professions of civil engineery, that I have long entertained an idea that cast iron anchors, I mean those of the largest sizes, would be found of equal if not superior strength to those of wrought iron; and though in a case where not only the lives of men, but the welfare of nations is concerned, no mercantile confideration ought to take place, nor ought any thing to be spared that can add to the perfection of so very material an utensil as that of the anchor; yet if, upon a fair and full trial, it shall appear that cast iron ones, of a proper composition of metal, are in reality equally or preserably to be depended upon, then the readiness, cheapness, and facility wherewith they are to be produced, appears to me a very sufficient reason (to say nothing of the encouragement of a British in contradistinction to a foreign production) why such a fair and full trial should be made as shall be sufficient to put the matter beyond a doubt.

I never supposed that any kind of cast iron would be equal in bearing a stress with that of wrought iron, even of a tolerable quality, provided the fize and shape of the matter to be formed of wrought iron is capable of being firmly welded, and united in one folid mass; for this reason, I cannot suppose any anchor can be formed of cast iron, that shall bear a stress equal with one of wrought metal, whose shank is in the smallest part not more than 3 inches, or 31 inches in diameter: but observing in such large anchors for first and second rate ships of war, as I have had the opportunity of seeing when broken, that the wrought bars of which they are composed are very impersectly welded and united together in the infide; and having also experienced on the other hand the very great strain that large masses of well-mixed cast iron will bear, when applied to the greatest stresses in mill and engine work, I have been naturally led to put the query, whether beyond some certain medium, that is, whether in those very large and heavy anchors for the largest, ships, the substitution of cast iron, instead of wrought, may not be in every respect useful and advantageous.

Had the trial you have communicated to me, made by the officers of his Majesty'ss yard at Deptford, appeared to me conclusive, I should have there rested the matter with them, as fully and fufficiently tried; but, with all due deference to those gentlemen, whose knowledge in their profession entitles them to the greatest respect from the public, I beg leave to say, that this is a new case, and therefore till it is tried, in a manner similar to that in which it is to be used, it is in fact no trial at all.

Had the proposition been to try whether a wrought or a cast iron anchor, or indeed a bar of metal of any size, would best bear the blows of an iron ram or beetle, the mode of trial was perfectly adapted to prove the point; and I am so far satisfied of the fact, as it turned out, that I even wonder that the palms were not broken by the hammers; but I conceive there is nothing like the collision of hard bodies in the real use of an anchor at sea; on the contrary, no stress can possibly be communicated more kindly than that of a ship to its anchor, through the intervention of a long cable. It is possible, in letting go an anchor, it may fall upon a rock, but I conceive an anchor is never let go in foul ground by design, and by choice, but yet it may happen and be necessary. The anchor in its descent having necessarily the cable to haul out after it, and the stock of the anchor, like the log, to haul croffways through the water, the velocity natural to the descent of heavy bodies is hindered from taking place in so great a degree, that let the water be ever so deep, the velocity wherewith it strikes the ground is very moderate, and with this further circumstance that must attend it, that, from the anchor stock and cable both conspiring to act as a rudder, the anchor will necessarily fall with its shank near a perpendicular direction, and therefore have the best chance of impinging upon some part of the crown that is fortified in the best manner to resist blows, as well as every other violence; besides, the rocks below the surface of the sea, being supposed a continuation of the strata above it, and nearly of the same hardness, they are comparative to iron generally fost bodies, and the hardest of them all that lay in masses in this kingdom, that we know of, would, by fuch a stroke, be bruised, less or more; and this is certain, that the effect of a stroke, where either of the bodies is bruised, or will rebound by elasticity, is widely different from what will happen when neither of them will give way in a sensible degree; I must therefore conclude, that there is not, nor can be, any thing in the real use of an anchor that is in any degree analagous to the stroke of an iron ram, much less to such a stroke applied crossways upon its shank.

The windmill, axis and oil-press that you cast for me the year before the last, the former has withstood the fury of all the storms that have happened since, without the least likelihood of injury; and yet one blow of the Deptford piling-ram, properly directed, would destroy it. The oil-press is in constant work, and every five or six minutes is subject to an alternate pressure and release from a equivalent to 300 tons of dead weight, tending directly to rend it in two; and yet I believe a single well-directed blow of a sledge hammer would break it. If the length of time of the use of these utensils is not thought sufficient, I must add, that in the year 1755, that is 27 years ago, for the first time, I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the

powers, what must happen from the brittleness of cast iron? It is sufficient to say, that not only those very pieces of cast work are still in work, but that the good effect has in the norm of England, where sirst applied, drawn them into common use, and I never heard of my one failing. Your own method of breaking up the largest iron guns is so an example to the same purpose, where the blow arising from the sall of an iron ball of 7 or 8 cwt. produces an effect that ten times the power of gunpowder would not; for the action of powder, though very quick, yet differs from the instantaneous action of a blow, in much the like manner as a line does from a surface.

The mode of trial that would appear to me conclusive would be as follows: I would take two anchors, as nearly of a weight and dimensions as possible, the one of wrought, the other of cast iron, not less than three tons weight each (two tons I think too much in favour of the wrought iron for a first trial,) and placing them at a competent distance in a right line, with the rings towards each other, for each I would dig a pit in the firm ground, capable of burying both the palms of each anchor: at the bottom of each pit I would fix, edgeways upward, a large elm plank of 10 inches or a foot thick, into the middle of which I would make a moderate perforation of about 3 inches, to receive the point of the fluke of each anchor these planks I would guard with piles in the securest manner possible, to prevent the point of a great pressure, from moving towards each other, and then well ramming up the whole with earth, so as to bury the anchor, the shanks of each to be inclined upwards, so that the rings may be at or near the surface.

Then having provided two pair of purchase-blocks capable of purchasing 15 or 20 tons each, with suitable tackle-falls, and cap-stands, crabs, or tooth and wheel gins, I would hook one block of each pair to the ring of one anchor, and the other to the other, securing every thing as much as possible; and the tackle-falls being made to go off to the capstands, each by a snatch block sideways, it is plain, that whatever strain is upon one anchor, the same will be on the other; I would then proceed to heave till something gave way, and which ever of them kept the ground, after the other, by failure, was drawn out of it, would be the anchor upon which I should be ready, in case of the greatest extremities, so pin my faith.

The expence of the trial I should think no object, for in case the cast-iron anchor was broke, and the other unhurt, there would be no loss but of a little labour, and was I to go to sea, I should chuse the anchor that had been so severely tried, in preservence of all others of the same size and kind; but if the wought iron one gave way, rence of all others of the same size and kind; but if the wought iron one gave way,

unhurt, then a discovery will result worth the price of 20 anchors.

In this manner, if the cast-iron anchor proved the conqueror, I would proceed to try those of a lesser weight, so as to find somewhat nearly the medium, at which the wrought iron anchor would have the preserence, keeping always on the safe side of the question.

These, gentlemen, after sull consideration, are the result of my genuine sentiments of this subject, which you have desired; and if sound useful towards determining a point that may be of much utility to the public service, shall think my pains and study well employed, and remain,

Gentlemen,

With much esteem and respect,

Your most humble fervant,

Austhorpe, February 7, 1782.

J. SMEATON.

END OF VOL. I